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STEAM SHIP CAPABILITY

BY

CHARLES ATHERTON.

SECOND EDITION



STEAM SHIP CAPABILITY.



THE
CAPABILITY
OF
STEAM SHIPS,
BASED ON THE MUTUAL RELATIONS OF
DISPLACEMENT, POWER, AND SPEED;
ILLUSTRATED BY
TABLES,
ADAPTED FOR
MERCANTILE REFERENCE.

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SECOND EDITION

LONDON:
JOHN WEALE, 59, HIGH HOLBORN.
1855.

106. h. 32.



WOOLWICH:
JOHN GRANT, PRINTER, 47, KING STREET.

PREFACE.

IN explanation of the object sought to be attained by the publication of the following Treatise, it may be premised that Shipping may now be regarded as in a state of transition ; for, though the use of Sail may not be superseded by the agency of Steam, it seems apparent that the co-operation of sail and steam will be universally introduced. Under this aspect of shipping interests, it is desirable that the public have the means of becoming familiar with the mutual relation of Steam-ship Displacement, Power, and Speed, in order that the conditions of Steam-ship mechanical and nautical efficiency may be foreknown, and that the commercial balance account between estimated Speed and Cost may be duly calculated : in short, it is the compound combinations of **DISPLACEMENT, POWER, and SPEED**, in relation to the **COST of FREIGHT**, which constitute the arithmetic of Steam-ship adaptation to the requirements of mercantile service.

Thus, to bring under view the mutual relations of Steam-ship Displacement, Power, and Speed, with reference to the Cost of Freight, is the task that has been attempted in this Essay. The results can only be regarded as approximate ; and the system of calculation is admissibly still open to corrective research ; but, being based on generalized data, derived from practical experience, it is expected that the **WORK** will present a substantially

correct digest of the CAPABILITIES of Steam as now applied to Navigation; and that it will point out a course of investigation not hitherto thrown open, and on which much labour may be usefully bestowed.

The primary matter, however, necessarily brought forward for consideration as being the base of all Steam-ship calculations as respects the mutual relation of Power and Speed, and therefore, indispensable to the prosecution of these inquiries, is a proposition for assigning some *definite* and *legalized* STANDARD VALUE to the term HORSE-POWER as the UNIT of power applicable to Steam-ship Navigation; by which Constant Quantity, marine engine contracts may, as regards the measure of power, be assimilated, and by which the available ENGINE-POWER of all steamers may be duly registered together with the Tonnage and the Displacement of the ship at a given draught; but this proposition is of a nature that can only be dealt with by legislative authority on representations backed by the greatest commercial weight; and should this Essay promote the realisation of a step so essential in the progress of *systematizing* the science of Steam-ship construction, and of Steam-ship adaptation and management, its publication will have conduced to public utility in a department of national enterprise of the utmost importance to the manufacturing and mercantile interests of the country.

CHARLES ATHERTON.

Woolwich Dockyard,
1st. March, 1853.

PREFACE
TO THE
SECOND EDITION.

THE Author avails himself of the opportunity afforded by a further issue of this Essay to extend the investigations so as to present a tabular exposition of estimated £ s. d. outlay actually incurred in the conveyance of Cargo per ton weight of cargo conveyed on any given passage, and to shew the degree in which such expenses are affected by *differences* in the Dynamic QUALITY of the Ship employed; also to enter more fully into a consideration of the *limitation* of the superior Dynamic capability which is admitted to be the inherent property of large ships as compared with smaller vessels.

The object of the Author in this publication has been to stimulate inquiry into the comparative qualities and capabilities for transport of Steam-ships and reduce the subject of comparative Steam-ship Capability for goods' transport, to some SYSTEM of Mercantile arithmetic. He does not aspire to having produced a finished work, but merely to have broken up ground in a neglected department of Mercantile pursuit,—the cultivation of which will not fail to be of national importance.

Woolwich Dockyard,
30th. September, 1854.

CONTENTS.

SECTION I., page 1 to 7.—The nominal Horse-power generally referred to in Steam-ship Navigation, and registered as the Engine-power, does not define the Motive-power capable of being developed by the Engines. Necessity for determining upon some specific amount of Power to be assigned to the term Horse-power, and to be legally recognised as the Standard Measure of the UNIT of Power implied by that term.

SECTION II., page 8 to 21.—The recorded test trials and duly authenticated performances of H.M. Steam-vessels RATTLER, FAIRY, ARROGANT, and HOGUE assumed as the base of calculations shewing the differences of Steam-ship locomotive performance which result from differences of Build and of Engine adaptation thereto; illustrated by Tables shewing the mutual relation of Displacement, Power, and Speed in Vessels built on those various types of form respectively.

SECTION III., page 22 to 40.—Tables (Series 1, Nos. 1 to 13) shewing the CAPABILITIES of Steam-ships on the type of H.M. Steam-sloop RATTLER, from 500 to 10,000 tons Displacement, embracing the mutual relation of Displacement, Power, Speed, Weight of Hull and Equipment, Coals, Freight, Time the coals will last, and the Distance capable of being traversed without re-coaling; with deductions shewing the progressively increasing difficulties which attend the realisation of increasing speed.

SECTION IV., page 41 to 60.—The mutual relation of Distance, Speed, Time, Coal, and Cargo; illustrated by Tables (Series 2, Nos. 1 to 13) constructed especially with reference to Passages of 500, 1,000, 2,000, 3,000, 4,500, and 6,000 nautical miles, with deductions shewing the proportional increase of expenses in the Engine department consequent on increasing speed, and the proportional reduction of Freight expenses per ton of Cargo, consequent on increased size of ships.

SECTION V., page 61 to 72.—Investigation as to the comparative extent to which the Cost of Freight *per ton weight of cargo* is affected by differences of original Construction as regards the Locomotive Properties of different ships, or by different degrees of *falling off* in the working condition of the Hull, Engines, and Boilers of the same ship.

SUPPLEMENT, page 73 to 89.—Shewing by approximate £ s. d. estimate, based on assumed data, the actual cost expenses of Freight per ton of Cargo conveyed, as affected by differences in the *Dynamic Quality* of the Hull, the *economic quality* of the Machinery and progressive *increase* in the Size of vessels, including vessels of hypothetical magnitude; also, shewing the superior dynamic capability of large ships compared with smaller vessels for the performance of any given service under the *same conditions* of speed and distance without re-coaling, and investigating the degree in which such superiority of large ships may become neutralized on long passages by the greater facilities for *re-coaling* that may be available to smaller vessels.

APPENDIX.

Exemplification of a method of constructing Diagrams, for determining the mutual relation of Displacement, Power, and Speed in vessels of analogous construction.

TABLE showing the number of REVOLUTIONS per minute which will be required in order that a Screw-Propeller of a given pitch may advance at a given speed per hour, slip not included.

SUPPLEMENTARY APPENDIX.

I. OCEAN STEAMERS. *Exposition in vindication of the statements expressed by the Author at the Institution of Civil Engineers, London, in a discussion on the Capabilities of the Large Class of Ocean Steamers.*

II. LETTERS, Nos. 1 and 2, on the Registration of Ships' Displacement and Engine-power; urging, that in addition to the Mercantile Tonnage, the DISPLACEMENT, also at certain specific lines of immersion be Registered; and that the ENGINE-POWER be Registered with reference to some definite measure as the legalised standard UNIT denoted by the term Horse-power.

III. TABLES, shewing the cubes of numbers from 5 to 25, rising by the decimal .01, and the cube root of the square of numbers rising gradually from 10 up to 50,000, for facilitating the reduction of the formula $\frac{V^3 D^{\frac{1}{2}}}{H.P.} = C$, whereby the Co-efficient or Index Number indicative of the Dynamic QUALITY of Steam-ships may be determined.

IV. Trial data, and deduced Index Number or Co-efficient of Dynamic Quality of H.M. Screw vessels "RATTLEB," "REYNARD," and "FAIRY."

ERRATA. { PAGE 15—Last line of Table D, for "3822," read 2822.
PAGE 28—Line 2, for $\frac{H.P.}{132,000}$, read $\frac{F.V.}{132,000}$.
PAGE 52, 53, AND 54—For "Index Number 871," read 862.

THE MUTUAL RELATIONS
OF
STEAM SHIP
DISPLACEMENT, POWER, AND SPEED;
ILLUSTRATED BY
TABLES
ADAPTED FOR
MERCANTILE REFERENCE:

SECTION I.

THE NOMINAL HORSE-POWER GENERALLY REFERRED TO IN STEAM-SHIP NAVIGATION AND REGISTERED AS THE ENGINE-POWER, DOES NOT DEFINE THE MOTIVE POWER CAPABLE OF BEING DEVELOPED BY THE ENGINES. NECESSITY FOR DETERMINING UPON SOME SPECIFIC AND EASILY MEASURABLE AMOUNT OF POWER TO BE ASSIGNED TO THE TERM HORSE-POWER, AND ADOPTED AS THE STANDARD MEASURE IMPLIED BY THAT TERM.

At a period when Steam Ship navigation is being prosecuted with unprecedented energy; when vessels of stupendous magnitude are being projected with a view to the circumnavigation of the globe; when a value is assigned to time, which urges the realization of speed to a degree which can be obtained only by the expensive resources of art being applied, not merely to co-operate with, but even to supersede the spontaneous but uncertain power of the wind; when commercial enterprise is thus

incurring the hazards of a new order of pecuniary investment, which may be beneficial or adverse to national interests according as prudence and skill, or indiscretion and error, may characterize the originating and conducting of such affairs; when moreover in such affairs, prosperity or loss depend on the discrimination with which the issues of Speed and Cost may be balanced against each other: under these circumstances, it may be expected that any attempt to illustrate, though but approximately, the mutual relation of the elements on which Steam Navigation is dependent, will be favorably entertained. With this hope, the following Tables showing approximately the mutual relation of Displacement, Power, Speed, and Cost, have been prepared and published.

Preparatory to the construction of these Tables, our primary object must be to determine upon some specific and measurable amount of motive power, to be assigned to the term horse-power (H.P.), and adopted as the base of calculation. It is to be observed that the definite measure of power originally implied by the term horse-power has, in marine practice, become totally superseded: the term horse-power, as now applied in marine engine contracts and practice, does not specifically determine, or limit, the gross working-power of the engines; but, the difference of working-power between one engine and another, though both, nominally, of the same horse-power and contracted for as such, can be shown to have been as much as 100 per cent.: that is, the one working up to double the power of the other; or, in other words, though marine engine contracts may have specifically fixed the *nominal* horse-power and the amount of money to be paid thereon, they have afforded no guarantee for the amount of *working* horse-power to be delivered; but the working-power has been left, in great

measure, to the voluntary discretion of the engine manufacturer.

Such discrepancies, which naturally result from contracts specifically binding only on one side, namely, as regards the amount of money to be paid, surely point out the necessity for the adoption of some system of commercial regulation in respect to the purchase and delivery of engine-power, whereby steam-ship INVESTMENT may be regulated more approximately in accordance with the accuracy of calculation, that generally distinguishes the prosecution of commercial enterprise.

The discrepancies above described between the nominal and the working-power of marine engines, are the more remarkable when it is considered that they are not attributable to the engines being produced by different makers, but apply to engines supplied under contract by the same manufacturers, and those of the highest repute, and even paid for at about the same rate per nominal horse-power, (for it is the nominal H.P. that generally rules the price), though producing, in effect, a difference of 100 per cent. and upwards on the cost of the *working-power*. Nevertheless, the term horse-power, from its seeming definiteness and simplicity, has become in the public mind so inveterately identified with marine engines, as describing proportionally the amount of their working-power, that any attempt on the present occasion to correct that delusive impression by altogether superseding the term horse-power, would be abortive, and probably defeat the desired utility of the present work as a Mercantile Tabular Reference: it is therefore proposed to retain the use of the term horse-power (H.P.) but to assign to it a *definite* and *measurable* value, corresponding to the ascertained Measure of the Working or Motive-power that on special

cases of the most successful engineering practice wherein the reputation of rival manufactures has been at stake, has been duly delivered and put into practical operation under that denomination; deducing an average of the working-power in such cases, not from the performance of a particular engine of a particular maker, but embracing a whole class of vessels of which the engines are the productions of various manufacturers.

In presenting these Tables with a view to so general a purpose as the introduction of an uniform system of engine-power-admeasurement as the base of marine engine contracts, and for the regulation of commercial transactions, it is proper to announce the specific examples of marine engine practice which have been assumed as constituting a measure of horse-power, in accordance, as above stated, with the most effective adaptation of the present day: accordingly, the measure of power now proposed to be assigned to the term horse-power is based on the average that has been actually produced by the Government Mail Packets *Banshee*, *Llewellyn*, *Caradoc*, *Vivid*, *Garland*, *Violet*, *Onyx*, *Princess Alice*, *Undine*, and *Elfin*; in which examples of marine engine performance it will be found that, if we take in each case, the pressure on the piston in pounds (p), as ascertained on trial by the Indicator, multiplied by the velocity of the piston in feet per minute (v), and divide by 132·000, the result will, on the average, give the Nominal horse-power at which the engines of the above-named ten vessels were contracted for, and have been duly fitted by the manufacturers, after deducting 15 per cent. in consideration that the engines, (or rather the boilers), when on trial, may probably have been urged to the extent of 15 per cent. beyond the limits that would

be maintained for continuous work: as shown by the following:—

STATEMENT No. 1.

SHOWING THE NOMINAL HORSE-POWERS OF TEN PACKETS, AS CONTRACTED FOR, AND THE WORKING POWERS ACTUALLY PRODUCED.

Names.	Nominal Horse-power per Contract.	Working power as determined on Trial, expressed in pounds pressure on the piston, moving at the rate of one Foot per minute.
BANSHEE	350	57·816·000 lbs. 1 Foot per minute.
LLEWELLYN	350	58·179·000
CARADOC	350	52·800·000
VIVID.....	160	25·179·000
GARLAND	120	17·655 000
VIOLET	120	19·536·000
ONYX.....	120	17·699·000
PRINCESS ALICE ...	120	14·190·000
UNDINE	110	14·619·000
ELFIN	40	8·085·000
Total	1840	285·758·000 lbs. 1 ft. per minute.

Deduct 15 per cent 42·863·000 (nearly)
 242·895·000

Average per Horse-power (H.P.) = $\frac{242·895·000}{1840} = 132·000$ lbs. 1 ft. per minute.

Hence, therefore, it appears that, in accordance with the engine performance of the ten vessels above referred to, a *marine horse-power* may be required to be the resultant of a pressure on the piston equivalent to 132·000 lbs., moving at the rate of one foot per minute; and it is proposed that such shall be the measure of power represented by the term horse-power (H.P.),

as applied to marine steam engines ; and that, whenever the term horse-power (H.P.) is referred to, whether it be the nominal horse-power referred to in the contract, or the indicated horse-power as ascertained by aid of the Indicator, or the effective horse-power as ascertained by aid of the Dynamometer, it shall be determined, as above described, by the divisor 132·000, and not by the divisor hitherto partially in use, (namely, 33·000) ; as this latter divisor, however appropriate it may have been at the period of its introduction and application to land-engine purposes, is now, (as shown by the foregoing statement, No. 1,) altogether superseded by engineering practice as applied to steam navigation.

In the examples of marine-engine performance above referred to, the cubical capacity of the cylinders for steam appears, on the average, to be about three-fourths of a cubic foot per horse-power, the steam being used at full pressure to about three-fourths of the stroke : it is, however, not proposed, in the present instance, to make any attempt to regulate or control, the details of practical construction ; the conditions as regards the size of the cylinder per horse-power, steam-pressure in the boiler, expansion in the cylinder, and working velocity of the piston at which the above measurable amount of motive power, per horse-power, is to be obtained, also the guaranteed ratio between the indicated horse-power as measured on the piston by aid of the Indicator, and the effective horse-power as determined by the Dynamometer, as well as the details of boiler construction, or the consumption of fuel with reference to the indicated H.P. determined as above deduced, may, optionally on the part of the purchaser, either be made the subject of specification and agreement, or be left to the judgment of a specially selected steamship contractor, thereby leaving an open field for

improvement and skill ; for on these and other like details of construction, the durability, trustworthiness and upholding cost of the engine, and economy of fuel, in proportion to the effective power, will be materially dependent : the only object now sought to be subjected to regulation is simply this ; that a HORSE-POWER (H.P.), shall signify *some* standard measure of motive power applicable to the present state of marine-engine practice ; so that a contract, which specifically defines the price at which an engine is to be paid for, per horse-power, and the engine-power at which the ship is to be registered, or nominally pass current, shall also guarantee some definite amount of power being delivered, and not leave the amount of motive power indefinite to the extent of 100 per cent., as at present, to the confusion of marine engineering as a scientific profession, to the subversion of manufacturing competition, to the defiance of all calculation as to steam-ship capability, to the derangement of mercantile speculation in matters of steam-ship investment and management, and to the utter misrepresentation of the data on which the rate of insurance, so far as dependant on the registered power of the engines, can be equitably regulated. In short, marine-engine HORSE-POWER requires to be determined and *legalized* as a STANDARD MEASURE of power ; and on the same principle that material quantities are regulated by the *standard yard*, and the *standard gallon*, and the *standard pound* weight, so, the motive power employed in steam navigation should be regulated and measured by the *standard marine horse-power*. The standard measure of power being thus determined, it is desirable that the registered power of all steam-vessels should accord therewith ; but, whether or not, the same standard should be applied to land-engines is not under present consideration.

SECTION II.

THE RECORDED TEST TRIALS, AND DULY AUTHENTICATED PERFORMANCES OF H.M. STEAM VESSELS "RATTLER," "FAIRY," "ARROGANT," AND "HOGUE," ASSUMED AS THE BASE OF CALCULATIONS, SHOWING THE DIFFERENCES OF STEAM SHIP LOCOMOTIVE PERFORMANCE, WHICH RESULT FROM THE DIFFERENCES OF BUILD, AND OF ENGINE ADAPTATION THERETO, ILLUSTRATED BY TABLES, SHOWING THE MUTUAL RELATION OF DISPLACEMENT, POWER, AND SPEED, IN VESSELS BUILT ON THESE VARIOUS TYPES OF FORM RESPECTIVELY.

IN the following tables the horse-power has been calculated according to the standard measure of power thus proposed to be assigned to it, (namely, equivalent to 132·000 lbs., raised at the rate of 1 foot per minute, as expressed by the formula, $H.P. = \frac{P.V.}{132 \cdot 000}$)* and the mutual relations between displacement, speed, and power (H.P.), in each of the four different classes of vessels referred to in the four tables, A, B, C, D, respectively, have been deduced by reference to the well authenticated performance of vessels of the various distinctive classes.

With the view of selecting the best examples of steamship performance as the base of these tabular deductions, enquiries as to the performance of merchant steam-vessels

* If this measure $H.P. = \frac{P.V.}{132 \cdot 000}$ be adopted as the standard by which the engine-power of steam-vessels is to be registered, it is expected that the registered H.P. of merchant steamers will on the general average be about half of the present nominal power.

have been made ; but, it has been found that mercantile records generally have reference to the nominal horse-power of the engines, and not to the working power ; or, to the register tonnage of the ship, and not to the ship's displacement ; or, whether nautical or statute miles have been the measure of speed is not always stated ; or, the rate of speed may not have been corrected according to the disturbing influence of current, tide, and wind ; consequently, such records do not furnish the specific data by which the *relative* locomotive performance of steam-ships can be accurately ascertained. The example set by the Admiralty, in publishing and circulating a tabular record of the constructive elements and experimental trials of the screw-ships of the Royal Navy, has not been met, or responded to, by any similar publication on the part of the proprietors of mercantile fleets. That this omission on the part of merchant steam fleet proprietors is injurious to their own interests may be inferred from the great advantages which have resulted to mining interests generally, by reason of the periodical publication of the constructive elements and working operation of Mine pumping engines ; and the interests of steam-ship proprietors and of Mine proprietors being analogous as regards the management of their motive power, it can scarcely be doubted that steam-ship efficiency would be greatly promoted by the engineering and ship-building rivalry that would, unquestionably, be consequent on the locomotive *DUTY* of all steam-ships being ascertained and *numerically* ranked like the Cornish pumping-engines. Notwithstanding, however, the *INTERESTS* that would be served by such comparisons of steam-ship performance, the published reports of merchant steam-ship trials are generally so deficient of details as regards the ship's *displacement* at time of trial and the

working power of the engines corresponding to the *speed* attained, that the compiler of the following Tables has but rarely met with any instance of such records affording the complete data on which any conclusion as to the real merit of the vessel could be satisfactorily deduced ; nor has he met with any case of screw steam-ship trial on which it has been shown that the locomotive performance of H.M. screw-ship *Rattler*, has been surpassed : the test of relative merit being determined by the index number resulting from the formula $\frac{V^3 \times D^{\frac{1}{2}}}{\text{IND. H.P.}}$ by which the screw-ships of the Royal Navy have been compared ; in which formula "V" represents the rate of speed, "D" the displacement at the time of trial, and "Ind. H.P." the motive power exerted by the piston as determined by aid of the instrument for measuring engine-power called the Indicator.

Referring therefore to the published records of the constructive data and trials of the screw ships of the R.N., the well-authenticated performances of H.M. screw-vessels *Rattler*, *Fairy*, *Arrogant*, and *Hogue*, have been selected as presenting good examples of their respective classes ; and the following Statement, No. 2, presents the constructive elements and trial data of these vessels ; from which, the subsequent Tables A, B, C, D showing, for each class of vessels respectively, the mutual relations of Displacement, Power, and Speed, have been deduced, it being assumed that the index number resulting from the formula $\frac{V^3 \times D^{\frac{1}{2}}}{\text{IND. H.P.}}$ would be constant for all vessels of which the ratio of constructive elements is similar to each other, and of which the engine-power may be equally effective, and consequently that variations in the index numbers will indicate differences of merit as regards the locomotive performances of the vessels thus put in comparison with each other.

STATEMENT No. 2.

Showing the constructive Elements and trial data of H. M. Steam Vessels RATTLER, tried January 23, 1845; FAIRY, tried April 5, 1845; ARROGANT, April 12, 1849; and HOGUE, tried December 18, 1850; from which the subsequent Tables A, B, C, D, have been respectively deduced.

Designations of the Tables. Vessels in H. M. Service, on the performance of which the Tables have been based.		ELEMENTS OF CONSTRUCTION.										Indicated Horse-power, calculated on the formula $H.P. = \frac{P.V.}{132 \cdot 000}$	SPEED PER HOUR. } Nautical Miles. Index number = $\frac{V^3 \text{ Dispt. } \frac{3}{4}}{H.P.}$	
		Length (L).	Breadth (B).	Mean draught of water (D).	Displacement (36 cubic feet to a Ton.)	Midship sectional area.	RATIO OF							
							Length to Breadth.	Breadth to Depth.	Dispt. in Cubit Feet to $L \times B \times D$.	Midship sectional area to $B \times D$.				
		FT. IN.	FT. IN.	FT. IN.	TONS	SQ. F.								
A	RATTLER .	176·6	32·8½	13·6	1078	330	5·39	2·42	·50	·75	109	9·64	862	
B	FAIRY.....	144·8	21·1½	4·10	168	71½	6·85	4·37	·41	·70	91	13·32	792	
C	ARROGANT.	200·0	45·8¾	18·10¼	2444	580	4·37	2·43	·51	·67	156	8·29	664	
D	HOGUE ...	184·0	48·4½	22·6	3080	804	3·80	2·15	·55	·74	203	8·33	602	

From the above statement it will be observed that the constructive elements as regards the Ratios of Length to Breadth are progressive, and include the limits of present practice for sea-going vessels: the ratio of Length to Breadth in *Hogue* being nearly four to one, and in *Fairy* nearly seven to one.

TABLE A.

Showing the mutual relation of Displacement, Power, and Speed, of vessels on the type of RATTLER, of which vessel the constructive elements are shown in the foregoing Statement, No. 2, observing that the H.P. is calculated by the formula, $H.P. = \frac{P.V.}{182.000}$, and that the Index Number is 862.

SPEED PER HOUR.		DISPLACEMENT IN TONS.											
Nautical Miles.	Statute Miles.	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	
		H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.
6	6.914	25	26	28	30	31	33	34	36	37	38	40	
7	8.066	40	42	45	47	50	52	54	57	59	61	63	
8	9.218	59	63	67	71	74	78	81	84	88	91	94	
9	10.370	84	90	95	100	106	111	115	120	125	129	134	
10	11.523	116	123	131	138	145	152	158	165	171	178	184	
11	12.675	154	164	174	183	193	202	211	219	228	236	245	
12	13.827	200	213	226	238	250	262	274	285	296	307	317	
13	14.980	254	271	287	303	318	333	348	362	376	390	403	
14	16.123	317	339	359	378	398	416	434	452	470	487	501	
15	17.284	391	416	441	465	489	512	534	556	578	599	620	
16	18.436	474	505	535	565	593	621	648	675	701	727	753	
17	19.589	568	606	642	677	712	745	778	810	841	872	902	
18	20.741	675	719	762	804	845	884	923	961	999	1035	1071	
19	21.893	794	846	897	946	994	1040	1086	1130	1174	1217	1260	
20	23.045	926	987	1046	1103	1158	1213	1266	1319	1369	1420	1469	

NOTE.—On the above type, a vessel of 5,000 tons Displacement would be propelled at the rate of 10 nautical miles an hour by 336 horse-power.

TABLE B.

Showing the mutual relation of Displacement, Power, and Speed, of vessels on the type of FAIRY, of which vessel the constructive elements are shown in the foregoing Statement, No. 2, observing that the H. P. is calculated by the formula, $H.P. = \frac{P.V.}{182.000}$, and that the Index Number is 792.

SPEED PER HOUR.		DISPLACEMENT IN TONS.											
Nautical Miles.	Statute Miles.	100	150	200	300	400	500	600	700	800	900	1000	
		H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.
6	6.914	6	8	10	12	15	17	19	21	23	25	27	
7	8.066	9	12	15	19	23	27	31	34	37	40	43	
8	9.218	14	18	22	29	35	41	46	51	56	60	65	
9	10.370	20	26	31	41	50	58	66	73	79	86	92	
10	11.523	27	36	43	57	69	79	90	100	109	118	127	
11	12.675	36	48	58	75	91	106	120	133	145	157	168	
12	13.827	47	62	75	98	119	138	155	172	188	204	219	
13	14.980	60	78	95	125	151	175	198	219	239	259	278	
14	16.123	75	98	119	156	188	219	247	274	299	324	347	
15	17.284	92	121	146	191	232	269	304	337	368	398	427	
16	18.436	112	146	177	232	281	326	369	408	446	483	518	
17	19.589	134	175	212	278	337	391	442	490	535	579	621	
18	20.741	159	208	252	331	400	465	525	581	636	688	737	
19	21.893	187	245	297	389	471	546	617	684	747	809	868	
20	23.045	218	285	346	453	549	637	720	797	872	943	1011	

NOTE.—On the above type, a vessel of 5,000 tons Displacement would be propelled at the rate of 10 nautical miles an hour by 370 horse-power.

TABLE C.

Showing the mutual relation of Displacement, Power, and Speed of vessels on the type of ARROGANT, of which vessel the constructive elements are shown in the foregoing Statement, No. 2, observing that the H.P. is calculated by the formula $H.P. = \frac{P.V.}{152 \cdot 000}$, and that the Index Number is 664.

SPEED PER HOUR.		DISPLACEMENT IN TONS.											
Nautical Miles.	Statute Miles.	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	
		H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.
6	6.914	52	53	55	56	58	60	61	63	65	66	68	
7	8.066	82	85	88	90	93	95	98	100	103	105	108	
8	9.218	123	127	131	135	139	142	146	150	153	157	161	
9	10.370	175	180	186	192	197	203	208	213	219	224	229	
10	11.523	240	247	255	263	271	278	285	293	300	307	314	
11	12.675	319	329	340	350	360	370	380	390	399	409	418	
12	13.827	414	426	441	454	467	480	493	506	518	530	542	
13	14.980	526	544	561	578	594	610	627	643	659	674	690	
14	16.123	657	679	701	722	742	763	783	830	823	842	861	
15	17.284	809	835	862	888	913	938	963	988	1011	1035	1059	
16	18.436	981	1013	1045	1077	1108	1138	1169	1198	1228	1257	1286	
17	19.589	1176	1215	1254	1291	1329	1365	1401	1437	1472	1507	1542	
18	20.741	1397	1443	1488	1533	1578	1621	1664	1706	1748	1789	1830	
19	21.893	1643	1697	1751	1804	1855	1906	1957	2007	2056	2105	2153	
20	23.045	1916	1979	2042	2103	2164	2223	2283	2341	2398	2455	2511	

NOTE.—On the above type, a vessel of 5,000 tons Displacement would be propelled at the rate of 10 nautical miles an hour by 441 horse-power.

TABLE D.

Showing the mutual relation of Displacement, Power, and Speed of vessels on the type of HOGUE, of which vessel the constructive elements are shown in the foregoing Statement, No. 2, observing that the H.P. is calculated by the formula, $H.P. = \frac{P.V.}{132.000}$, and that the Index Number is 602.

SPEED PER HOUR.		DISPLACEMENT IN TONS.											
Nautical Miles.	Statute Miles.	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	
		H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	
6	6.914	75	76	78	79	81	83	84	86	87	89	90	
7	8.066	118	121	124	126	129	131	134	136	139	141	143	
8	9.218	177	181	185	188	192	196	199	203	207	210	214	
9	10.370	252	257	263	268	273	279	284	289	295	299	305	
10	11.523	345	353	360	368	375	382	390	397	404	411	418	
11	12.675	459	470	479	489	499	509	519	528	538	547	557	
12	13.827	596	610	623	636	648	661	673	686	698	710	722	
13	14.980	758	775	792	808	824	840	856	872	888	903	919	
14	16.123	947	968	989	1009	1029	1046	1069	1089	1108	1128	1147	
15	17.284	1165	1190	1216	1241	1266	1291	1315	1340	1363	1387	1411	
16	18.436	1414	1445	1476	1506	1536	1567	1596	1625	1655	1683	1712	
17	19.589	1695	1733	1770	1806	1843	1878	1914	1950	1984	2019	2054	
18	20.741	2012	2057	2101	2144	2188	2230	2273	2314	2356	2397	2438	
19	21.893	2367	2420	2472	2523	2573	2623	2673	2722	2771	2819	2868	
20	23.045	2761	2822	2883	2942	3001	3059	3118	3175	3232	3288	3345	

NOTE.—On the above-type, a vessel of 5,000 tons Displacement would be propelled at the rate of 10 nautical miles an hour by 485 horse-power.

Referring to the foregoing Tables, A, B, C, D, according to the class of vessel that may be in question, the marine horse-power (H.P.) required to propel a vessel of a given displacement at any required speed from six to twenty nautical miles an hour will be at once determined—for example, a vessel on the type of *Rattler*, of 1,500 tons displacement, to be propelled at the rate of ten nautical miles per hour, will require 152 horse-power. In like manner, the speed corresponding to a given amount of displacement and power, or the required displacement to attain a given speed with a given amount of power will be seen by inspection ; also, the theoretical results presented by these Tables can be compared with the actual results of steam-ship trials. Whence, it may be determined in what degree the locomotive performances of different vessels may be respectively superior or inferior to the analagous type of ship on which the Table is based ; whereby, the relative merits as regards the locomotive performance of different vessels may be compared, and the cause of difference be enquired into and approximately ascertained.

These Tables may be referred to as indicating the following general principles in connection with Steam Navigation, viz. :—

It may be remarked that the vessels *Rattler*, *Fairy*, *Arrogant*, and *Hogue* are of such different classes that the elements of construction of their immersed bodies embrace the ordinary range of build, whether for packet service or for cargo. In order, therefore, to illustrate the differences of locomotive efficiency, which are incidental to the differences of construction of these four vessels, the notes annexed to the Tables A, B, C, D, may be referred to, by which it appears that vessels of 5,000 tons displacement, and having their immersed bodies constructed on the respective types of

Rattler, *Fairy*, *Arrogant*, and *Hogue*, would respectively be propelled at the rate of ten nautical miles per hour by 336 H.P., 370 H.P., 441 H.P., and 485 H.P., which numbers are in the proportions of 100, 110, 131, and 144, thus affording a general idea of the differences in regard to Power, which would be required, in order that vessels of these different constructions may produce similar results, that is, in order that equal displacement may be propelled at equal speed, and since the immersed bodies of *Arrogant* and *Hogue* are analogous to the general form of ships constructed with a view to sailing properties, we may infer from the above calculations the amount of sacrifice likely to be incurred by applying the screw-propeller to vessels originally built for sailing, instead of building vessels of a form better adapted for mechanical propulsion; or at least, this method of investigation will assist in determining on the mercantile propriety of such conversion of existing stock in comparison with building new ships.

On inspecting the Tables A and B, they will be found to present this remarkable result: namely, that the Table A, on the type of *Rattler*, the length of which ship is under five-and-a-half times the breadth, gives a higher result than Table B, on the type of *Fairy*, the length of which ship is nearly seven times the breadth; for, by Table A, it appears that a vessel of 1,000 tons displacement on the the type of *Rattler* will be propelled at the rate of fifteen nautical miles per hour by 391 horse-power; but, by Table B, on the type of *Fairy*, it will require 427 horse-power to produce the same result, though the elements of construction, on which Table B is based, are, as regards the ratio of length to breadth, much more analogous than those of Table A to the elements now generally received by steam-ship constructors as most conducive to speed. In fact, the locomotive

performance of H.M. screw-ship *Rattler* has, hitherto, been found superior to that of any other screw vessel, whether in the Royal Navy or in the merchant service, with which comparison has been instituted, as shown by its giving the highest index number of locomotive performance, when tested by the formula referred to ; but, having now held this pre-eminent position for twelve years (for, *Rattler* was designed in "1841,") it is, of course, to be expected that amongst the multiplicity of rivals of modern construction, and the confident pretensions to superiority advanced successively in favor of each ship of the most recent build, the *Rattler* must soon assume a secondary place : until, however, such superiority shall be realized the *Rattler* may be regarded as a type of form and of engine adaptation thereto worthy of the study of steam-ship constructors * and the attention of steam-ship proprietors ; accordingly, a further Table, E, has been prepared, which we may call the Key Table for vessels on the type of *Rattler*, extending the range of displacement to dimensions which exceed the greatest displacement of mercantile shipping hitherto built, thus affording the means of comparison with modern ships, and also a test of the progressive advancement of modern science and art in the important work of steam-ship construction as exemplified by a progressively improving scale of commercial efficiency.

* In an Essay on "Marine Engine Classification," published by Weale, London, Mr. Atherton has endeavoured to ascertain, from a comparison of RATTLE with other screw-ships, what *principles* of engine construction have conduced to the best results ; and it is worthy of remark that the effective power of RATTLE, as tested at the Dynamometer at Woolwich, 29th September, 1851, was found to be 84 per cent. of the gross indicated power, being a higher per centage of effective power than is known to have been attained by any *paddle-wheel* vessel.

TABLE E.
*Showing the Mutual Relation of DISPLACEMENT, POWER, and SPEED, for Vessels
on the type of RATTIER.*

$$\text{Index Number 862, and H.P.} = \frac{\text{P.V.}}{182.000}.$$

SPEED PER HOUR.	DISPLACEMENT IN TONS.																					
	N. MILES.	250	50	750	1000	1250	1500	1750	2000	2250	2500	2750	3000	3500	4000	4500	5000	6000	7000	8000	9000	10000
6		H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
7		10	16	20	25	29	33	36	40	43	46	49	52	58	64	68	73	83	91	100	108	116
8		16	25	32	40	46	52	58	63	68	73	78	83	92	100	108	115	131	145	159	172	184
9		24	37	49	59	69	78	86	94	102	109	116	123	137	148	162	172	196	217	237	256	276
10		33	53	70	84	97	111	122	134	145	155	166	175	194	212	229	245	279	309	338	365	388
11		46	73	96	116	134	152	168	184	199	213	227	241	267	292	316	336	383	423	463	501	536
12		61	97	127	154	178	202	223	245	265	284	302	320	355	388	419	448	510	564	616	667	712
13		79	126	165	200	232	262	290	317	343	368	392	416	461	504	545	581	660	732	800	865	928
14		101	160	210	254	295	333	369	403	437	468	499	529	586	640	683	739	840	931	1017	1100	1180
15		126	200	262	317	368	416	461	504	545	585	623	661	732	800	865	928	1049	1162	1270	1374	1472
16		155	246	322	390	453	512	567	620	671	720	767	813	901	984	1064	1135	1291	1429	1562	1690	1812
17		188	299	391	474	550	621	688	753	814	873	931	987	1093	1196	1292	1377	1567	1735	1897	2051	2200
18		226	358	469	568	659	745	825	902	976	1047	1116	1183	1310	1432	1549	1652	1878	2080	2274	2460	2636
19		268	425	557	675	783	884	980	1071	1159	1243	1324	1405	1556	1700	1839	1961	2230	2470	2700	2921	3132
20		315	500	655	794	921	1040	1152	1260	1363	1462	1558	1652	1830	2000	2163	2307	2623	2905	3176	3435	3684
		367	583	765	926	1074	1213	1344	1469	1590	1705	1817	1927	2134	2333	2523	2690	3059	3388	3704	4007	4296

TABLE F.

As ships are generally spoken of with reference to their Tonnage (Builder's Measurement) and not with reference to their Displacement, the following Table shows the mutual relation of TONNAGE (old rule,) DISPLACEMENT in tons, and the corresponding length, breadth, and mean draught of ships constructed on the proportions of RATTLER.

DISPLACEMENT IN TONS	250	500	750	1000	1250	1500	2000	2500	3000	4000	5000	6000	8000	10000
DIMENSIONS PROPORTIONAL TO RATTLER.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.	FT. IN.
	LENGTH (L)	108.5	130.7	156.5	172.2	185.5	197.1	216.11	233.7	248.3	273.3	312.9	344.3	370.10
	BREADTH (B)	20.1	25.4	29.0	31.11	34.44	36.64	40.24	43.31	46.0	50.74	57.114	63.91	68.84
MEAN DRAUGHT (D)	8.34	10.54	11.114	13.2	14.24	15.1	16.7	17.104	19.0	20.11	22.64	23.11	26.4	28.44
TONNAGE (OLD MEASUREMENT)	207	414	621	828	1085	1242	1656	2070	2484	3312	4140	4969	6625	8281

From the foregoing Table, E, it appears that the power required to propel steam-ships of similar build at a given speed does not increase in the same proportion as the size or tonnage of the ships, for, by inspecting the Table we observe, that if a ship of 500 ton's displacement be propelled at the rate of fourteen nautical miles per hour by 200-horse power, a ship on the same type of build, but of 4000 tons, being *eight times the displacement*, will be propelled at the same rate of speed by 800-horse power, being only *four times the power*. It appears also that a considerable decrease of displacement, consequent on the decreased immersion of the same ship, by reason, for instance, of the consumption of fuel during a long passage, will, if the same power be exerted, be attended with but a comparatively small increase of speed, for example, if 3000 ton's displacement (see Table E) be propelled at the rate of ten nautical miles an hour by 241 horse-power, the reduction of displacement to 2000 tons, caused by the consumption of 1000 tons of fuel, being a reduction of *one third*, will, with about the same horse-power (viz., 245 H.P.,) be attended with an acceleration of speed to eleven nautical miles, being an increase of *one tenth* only, supposing the operation of the screw to be equally effective when working at its reduced immersion. Hence, if the working power during a long passage be constant, the speed of the vessel, when at the *mean displacement*, will give very nearly the average speed of the passage under steam; accordingly, the following Tables, illustrating the CAPABILITIES of steam ships, have been calculated with reference to the *mean displacement* consequent on the gradual consumption of coal during the passage.

SECTION III.

TABLES INTENDED TO SHOW THE CAPABILITIES OF STEAM-SHIPS ON THE TYPE OF H.M.S. "RATTLER," FROM FIVE HUNDRED TO TEN THOUSAND TON'S DISPLACEMENT, EMBRACING THE MUTUAL RELATION OF DISPLACEMENT, POWER, SPEED, WEIGHT OF HULL AND EQUIPMENT, COALS, FREIGHT, TIME THE COALS WILL LAST, AND THE DISTANCE CAPABLE OF BEING TRAVERSED WITHOUT RE-COALING ; WITH DEDUCTIONS, SHOWING THE PROGRESSIVELY INCREASING DIFFICULTIES WHICH ATTEND THE REALISATION OF INCREASING SPEED.

In illustration of the further application of the foregoing Tables to the solution of enquiries as to the CAPABILITIES of steam ships, the following SERIES, Nos. 1 to 13 inclusive have been constructed as TABLES OF REFERENCE for ascertaining, approximately, the CAPABILITIES of ships of various sizes, for example :—500 Tons mean Displacement 750, 1000, 1250, 1500, 2000, 2500, 3000, 4000, 5000, 6000, 8000, and 10,000 tons. This series of calculations has been based on the assumption that the vessels shall have been constructed, both as regards the hull and the adaptation of machinery thereto, on elements capable of realising a degree of locomotive performance not inferior to that attained by H.M. screw steam-vessel *Rattler*, as indicated by the index number deduced from the formula $\frac{V^3 \times D^{\frac{5}{4}}}{H.P.}$ being not less than 862, in which formula $H.P. = \frac{P.V.}{182'000}$, the unit of power being thus assumed at 132'000 lbs. raised one foot per minute,

agreeably to the engineering practice, which has been realised in H.M. packets before referred to. These Tables present a system of investigation, whereby steam-ship proprietors may approximately determine whether or not a Stock vessel, proposed for any contemplated service, may be expected to meet the requirements of the service in regard to distance to be steamed without re-coaling, time of passage, and amount of displacement available for passengers and cargo, also to aid them, in the case of building new ships, in originally fixing upon such a size and class of ship, and such an amount of engine-power in proportion to the ship's displacement, as may be most suitable for the specific object in view, observing, that in these Tables, the weight of the ship's hull and equipment ready for sea, exclusive of engines, coals, and cargo, is taken at 40 per cent. of the mean displacement; the weight of the engines and boilers complete is taken at one ton per H.P., and the consumption of fuel at four cwt. per H.P. per day of twenty-four hours; * also, the favorable and adverse influences of wind and current are supposed, on the average, to balance.

* The weight of the Hull and Equipment, with reference to the mean displacement, will be materially dependant on the build of the ship; and the unit of H.P. having been taken at 132·000 lbs. raised one foot per minute (which is about double the ordinary average commercial unit of nominal H.P.), the assumed weight of one ton per H.P. for the engines, and four cwt. per H.P. per day for the consumption of fuel, is nearly in accordance with the best realised practice of the present day. The saving of weight which will, doubtless, be effected by improvements in ship, engine, and boiler construction, will increase the proportion of displacement, available for freight, above the limit calculated upon in the Tables, which have been based on data already realised.

SERIES 1.—TABLE No. 8.

Calculated for the mean DISPLACEMENT of 3000 TONS. Index Number 862, and H.P. = $\frac{\text{H.P.}}{182 \cdot 000}$.

SPEED—PER HOUR.	HORSE-POWER.		WEIGHT OF HULL AND ENGINES.		COAL. 150 TONS.			COAL. 300 TONS.			COAL. 600 TONS.			COAL. 900 TONS.			COAL. 1200 TONS.		
	N. M.	H. P.	TONS.		Available	Steaming time.	Steaming distance.	Available	Steaming time.	Steaming distance.	Available	Steaming time.	Steaming distance.	Available	Steaming time.	Steaming distance.	Available	Steaming time.	Steaming distance.
6	6	52	1252	1673	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.
7	7	83	1263	1642	9. 1	1518	1567	18. 2	3036	4154	1448	57.17	8307	1298	86.13	12461	1148	115. 9	16615
8	8	123	1323	1602	6. 2	1170	1527	12. 5	2341	3036	1417	36. 3	6072	1267	54. 5	9109	1117	72. 7	12145
9	9	175	1375	1550	4. 7	926	1475	8.14	1852	1852	1377	24. 9	4681	1227	36.14	7022	1077	48.19	9363
10	10	241	1441	1484	3. 3	747	1409	6. 5	1494	1494	1325	17. 3	3703	1175	25.17	5555	1025	34. 7	7407
11	11	320	1520	1405	2. 8	619	1330	4.16	1237	1237	1180	9. 9	2475	1109	18.16	4481	959	24.21	5975
12	12	416	1616	1309	1.19	519	1234	3.15	1088	1088	1084	7. 5	2077	934	10.19	3115	784	14.10	4154
13	13	529	1729	1196	1.10	443	1121	2.20	885	885	971	5.16	1770	821	8.12	2656	671	11. 8	3541
14	14	661	1861	1064	1. 3	381	989	2. 6	762	762	839	4.13	1525	689	6.19	2287	539	9. 2	3050
15	15	813	2013	912	0.22	332	837	1.20	664	664	687	3.17	1328	537	5.13	1993	387	7. 9	2657
16	16	987	2187	738	0.18	292	663	1.12	583	583	513	3. 1	1167	363	4.13	1750	213	6. 2	2334
17	17	1183	2383	542	0.15	259	467	1. 6	517	517	317	2.13	1034	167	3.19	1552	17	5. 2	2069
18	18	1405	2605	320	0.13	232	245	1. 2	461	461	95	2. 3	922	0					
19	19	1652	2852	73	0.11	207	0												
20	20	1927	3127	0															

SERIES 1.—TABLE No. 10.
Calculated for the mean DISPLACEMENT of 5000 TONS. Index Number 862, and H.P. = $\frac{H.P.}{182-000}$.

SPEED—PER HOUR.	H. P.	WEIGHT OF HULL AND ENGINES.	COAL. 250 TONS.			COAL. 500 TONS.			COAL. 1000 TONS.			COAL. 1500 TONS.			COAL. 2000 TONS.		
			Available	Steaming time.	Distance.	Available	Steaming time.	Distance.	Available	Steaming time.	Distance.	Available	Steaming time.	Distance.	Available	Steaming time.	Distance.
N. M.	TONS.	TONS.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.
6	73	2073	2802	17·3	2466	2677	34·6	4931	2427	68·12	9863	2177	103·18	14794	1927	137·0	19726
7	115	2115	2760	10·21	1826	2635	21·18	3652	2385	43·11	7304	2135	65·5	10956	1885	86·23	14609
8	172	2172	2703	7·6	1395	2578	14·13	2791	2328	29·2	5581	2078	43·14	8372	1828	58·3	11163
9	245	2245	2630	5·2	1102	2505	10·5	2204	2255	20·10	4408	2005	30·15	6612	1755	40·20	8816
10	336	2336	2539	3·17	893	2414	7·11	1786	2164	14·21	3571	1914	22·7	5357	1664	29·18	7143
11	448	2448	2427	2·19	737	2302	5·14	1473	2052	11·4	2946	1802	16·18	4419	1552	22·8	5893
12	581	2581	2294	2·4	619	2169	4·7	1239	1919	8·14	2478	1669	12·21	3717	1419	17·5	4957
13	739	2739	2136	1·17	528	2011	3·9	1055	1761	6·18	2111	1511	10·3	3166	1261	13·13	4222
14	923	2923	1952	1·8	455	1827	2·17	910	1577	5·10	1820	1327	8·3	2730	1077	10·20	3640
15	1135	3135	1740	1·2	396	1615	2·5	793	1365	4·10	1586	1115	6·14	2379	865	8·19	3172
16	1377	3377	1498	0·22	349	1373	1·20	697	1123	3·15	1394	873	5·10	2091	623	7·6	2789
17	1652	3652	1223	0·18	309	1098	1·12	617	848	3·1	1284	598	4·13	1851	348	6·1	2469
18	1961	3961	914	0·15	275	789	1·7	550	539	2·13	1101	289	3·19	1651	39	5·2	2202
19	2307	4307	568	0·13	247	443	1·2	494	193	2·4	988	0					
20	2690	4690	185	0·11	223	60	0·22	446	0								

SERIES I.—TABLE No. 12.
Calculated for the mean DISPLACEMENT of 8000 TONS. Index Number 862, and. H.P. = $\frac{P.V.}{132-000}$.

SPEED—PER HOUR.	H. P.	WEIGHT OF HULL AND ENGINES.	COAL. 400 TONS.			COAL. 800 TONS.			COAL. 1600 TONS.			COAL. 2400 TONS.			COAL. 3200 TONS.		
			Available	Steaming time.	Steaming distance.	Available	Steaming time.	Steaming distance.	Available	Steaming time.	Steaming distance.	Available	Steaming time.	Steaming distance.	Available	Steaming time.	Steaming distance.
N. M.		TONS.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.
6	100	3300	4500	20·0	2380	4300	40·0	5760	8900	80·0	11520	3500	120·0	17280	3100	160·0	23040
7	159	3359	4441	12·14	2113	4241	25·4	4226	8841	50·8	8453	3441	75·11	12679	3041	100·15	16906
8	237	3437	4363	8·11	1620	4163	16·21	3240	3793	33·18	6481	3363	50·15	9721	2963	67·12	12962
9	338	3538	4262	5·22	1278	4062	11·20	2556	3662	23·16	5112	3262	35·12	7669	2862	47·8	10225
10	463	3663	4137	4·8	1037	3937	8·15	2073	3537	17·7	4147	3137	25·22	6220	2737	34·13	8294
11	616	3816	3984	3·6	857	3784	6·12	1714	3384	13·0	3428	2984	19·11	5142	2584	25·23	6856
12	800	4000	3800	2·12	720	3600	5·0	1440	3200	10·0	2880	2800	15·0	4320	2400	20·0	5760
13	1017	4217	3583	1·23	613	3383	3·22	1227	2983	7·21	2453	2583	11·19	3680	2183	15·17	4907
14	1270	4470	3330	1·14	529	3130	3·4	1058	2730	6·7	2116	2330	9·10	3175	1930	12·14	4233
15	1562	4762	3038	1·7	461	2838	2·13	922	2438	5·3	1843	2038	7·16	2765	1638	10·6	3687
16	1897	5097	2703	1·1	405	2503	2·3	810	2103	4·5	1619	1703	6·7	2429	1303	8·10	3239
17	2274	5474	2326	0·21	359	2126	1·18	718	1726	3·12	1435	1326	5·6	2153	926	7·1	2871
18	2700	5900	1900	0·18	320	1700	1·12	640	1300	2·23	1280	900	5·10	1920	500	5·22	2560
19	3176	6376	1424	0·15	287	1234	1·6	574	824	2·12	1148	424	3·18	1723	24	5·1	2297
20	3704	6904	896	0·13	259	696	1·2	518	296	2·4	1037	0					

SERIES I.—TABLE NO. 13.
Calculated for the mean DISPLACEMENT of 10,000 TONS. Index Number 862, and H.P. = $\frac{P.V.}{132,000}$.

SPEED—FEET HOUR.	H. P.	WEIGHT OF HULL AND ENGINES.	COAL. 500 TONS.			COAL. 1000 TONS.			COAL. 2000 TONS.			COAL. 3000 TONS.			COAL. 4000 TONS.		
			Available	Steaming time	Steaming distance.	Available	Steaming time.	Steaming distance.	Available	Steaming time.	Steaming distance.	Available	Steaming time.	Steaming distance.	Available	Steaming time.	Steaming distance.
N. M.	TONS.	TONS.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.	TONS.	D. H.	N. M.
6	116	4116	5634	21.13	3103	5384	43.2	6207	4884	86.5	12414	4384	129.7	18621	3884	172.10	24828
7	184	4184	5566	13.14	2283	5316	27.4	4555	4816	54.8	9130	4316	81.12	13695	3816	108.17	18261
8	276	4276	5474	9.1	1739	5224	18.3	3478	4734	36.6	6956	4224	54.8	10434	3724	72.11	13913
9	388	4388	5362	6.11	1392	5112	12.21	2783	4612	25.19	5567	4112	38.16	8350	3612	51.13	11134
10	536	4536	5214	4.16	1119	4964	9.8	2239	4464	18.16	4477	3964	27.33	6716	3464	37.7	8955
11	712	4712	5038	3.12	927	4788	7.1	1854	4288	14.1	3708	3788	21.1	5562	3288	28.2	7416
12	928	4928	4822	2.17	776	4572	5.9	1552	4072	10.19	3103	3572	16.4	4655	3072	21.13	6207
13	1180	5180	4570	2.3	661	4320	4.6	1322	3820	8.11	2644	3320	12.17	3966	2820	16.23	5288
14	1472	5472	4278	1.17	571	4028	3.10	1141	3528	6.19	2282	3028	10.4	3423	2328	13.14	4565
15	1812	5812	3938	1.9	497	3688	2.18	993	3188	5.12	1986	2688	8.6	2979	2188	11.1	3973
16	2200	6200	3550	1.3	436	3300	2.7	873	2800	4.13	1745	2300	6.19	2618	1800	9.2	3491
17	2636	6636	3114	0.23	387	2864	1.22	774	2364	3.19	1548	1864	5.16	2322	1364	7.14	3096
18	3132	7132	2618	0.19	345	2368	1.14	689	1868	3.5	1379	1368	4.19	2068	868	6.9	2758
19	3684	7684	3066	0.16	309	1816	1.9	619	1316	2.17	1238	816	4.1	1857	316	5.10	2476
20	4296	8296	1454	0.14	279	1204	1.4	559	704	2.8	1117	204	3.12	1676	0		

The required increase of power and consequent decrease of cargo attendant on the realisation of an increased rate of speed by the agency of steam, as now applied in marine navigation, are strikingly developed by the foregoing Tables, for example:—

By Table No. 1, it appears that a ship of 500 tons' mean displacement, if fitted to run at EIGHT nautical miles per hour, would convey 163 tons of cargo on a passage of 5192 miles; but, if fitted with the increased power required for TWELVE nautical miles per hour, the same vessel would convey 74 tons of cargo on a passage of 2304 miles; being only *half* the cargo and *half* the distance.

By Table No. 3, a ship of 1000 tons' mean displacement, if fitted to run at EIGHT MILES per hour, would convey 341 tons of cargo a distance of 6512 miles; but, if fitted for FOURTEEN MILES per hour, the same vessel would convey 83 tons of cargo a distance of 2114 miles; being only *one-fourth* the cargo and *one-third* the distance.

By Table No. 7, a ship of 2500 tons' mean displacement, if fitted to run at EIGHT MILES per hour, would convey 891 tons of cargo a distance of 8807 miles; but, if fitted for SIXTEEN MILES per hour the same ship would convey 127 tons of cargo a distance of 2199 miles; being only *one-seventh* the cargo and *one-fourth* the distance.

By Table No. 11, a ship of 6000 tons' mean displacement, if fitted to run at EIGHT MILES per hour, would convey 2204 tons of cargo a distance of 11,755 miles; but, if fitted for EIGHTEEN MILES per hour the same vessel would convey 170 tons of cargo a distance of 2325 miles; being only *one-thirteenth* part of the cargo and about *one-fifth* of the distance.

By Table No. 13, a ship of 10,000 tons' mean dis-

placement, if fitted to run at EIGHT MILES per hour, would convey 3724 tons of cargo a distance of 13,913 miles; but, if fitted to run at TWENTY MILES per hour, the same vessel would convey 204 tons a distance of 1676 miles; being only *one-eighteenth* part of the cargo and *one-eighth* of the distance.

The *extreme* limit of SPEED capable of being achieved by a steam-vessel of given size, will, of course, be dependant on the lightness of the hull and equipment, lightness of machinery per H.P., economy of consumption of fuel per H.P., and on the construction of the hull and the engine adaptation thereto, being such as to give a high rate of locomotive performance. These are subjects of practical construction; and it is impossible to assign any definite limits to promissory improvements, or to the hazards that may be recklessly incurred in the pursuit of fame by sacrificing strength to the attainment of lightness; but, as regards each of the above-mentioned particulars, the assumed data on which the Tables, No. 1 to 13, have been calculated, are believed to be favorable for the attainment of a high result, and such as have rarely, if ever, been combined in any one ship. It is therefore submitted that the results indicated by these Tables are of the highest order that present practice will justify being *calculated* upon, however sanguine may be the opinion as to the practicability of these results being surpassed. Without any disparagement therefore of science, and with due appreciation of the improvements which constructive talent may, and undoubtedly will, confer on steam navigation, the following further remarks on the Tables may be adduced as indicating the *limits* of speed and distance that under present circumstances may be reasonably entertained as to the probable capabilities of vessels suitably constructed for

sea service. Referring, therefore, to the Tables, we observe as follows :—

By Table No. 1, it appears that a vessel of 500 tons' mean displacement, may not be expected to attain the speed of 17 nautical miles per hour, but may make a passage of 720 miles at 15 nautical or $17\frac{1}{4}$ statute miles per hour.

By Table No. 2, a vessel of 750 tons' mean displacement may not be expected to attain the speed of 18 nautical miles per hour, but may make a passage of 368 miles at 16 nautical or $18\frac{1}{2}$ statute miles per hour.

By Table No. 3, a vessel of 1000 tons' mean displacement may not be expected to attain the speed of 19 nautical miles per hour, but may make a passage of 357 miles at 17 nautical or $19\frac{1}{2}$ statute miles per hour.

By Table No. 6, a vessel of 2000 tons' mean displacement may not be expected to attain the speed of 20 nautical miles per hour, but may make a passage of 403 miles at 18 nautical or $20\frac{3}{4}$ statute miles per hour.

By Table No. 8, a vessel of 3000 tons' mean displacement may not be expected to attain the speed of 21 nautical miles per hour, but may make a passage of 207 miles at 19 nautical or 22 statute miles per hour.

By Table No. 10, a vessel of 5000 tons' mean displacement may not be expected to attain the speed of 22 nautical miles per hour, but may make a passage of 446 miles at 20 nautical or 23 statute miles per hour, carrying about 60 tons of freight.

Thus it appears, that to attain the speed of 20 nautical miles, or 23 statute miles per hour, for a passage of 446 nautical miles, a vessel of about 5000 tons'

mean displacement (probably not less than 4140 tons builders' measure) would be required, and even with a vessel of this magnitude, the displacement would be so appropriated by the weight of machinery, leaving 60 tons only available for cargo, that the vessel could only be regarded as a mail and passenger packet, and not adapted for general merchant service.

It however appears, by Table No. 13, that a ship of the unprecedented size of 10,000 tons' mean displacement, if fitted to run at 20 nautical miles per hour, may be expected to convey 1454 tons of cargo a distance of 279 miles; or, 1204 tons of cargo a distance of 559 miles; or, 704 tons of cargo a distance of 1117 miles; or, 204 tons of cargo a distance of 1676 miles.

Such is the limited commercial result of a vessel, even of the unprecedented size of 10,000 tons' mean displacement (or about 8281 tons, builders' measurement), if fitted to run at 20 nautical miles per hour, viz. :—conveying 204 tons of cargo a distance of 1676 miles only; and if we extend the calculation for the distance of 6000 miles, at the rate of 20 miles per hour, by the agency of steam *as now practised*, it will be found that the calculated result presents an array of figures *commercially* beyond the limit of all serious contemplation, especially when viewed with reference to the mutual relation of SPEED and COST, which is purposed to be the subject of the following Section.

SECTION IV.

THE MUTUAL RELATION OF DISTANCE, SPEED, AND COST OF FREIGHT PER TON ; ILLUSTRATED BY TABLES CONSTRUCTED ESPECIALLY WITH REFERENCE TO PASSAGES OF FIVE HUNDRED, ONE THOUSAND, TWO THOUSAND, THREE THOUSAND, FOUR THOUSAND FIVE HUNDRED, AND SIX THOUSAND NAUTICAL MILES.

WITH a view to illustrate the relative CAPABILITIES of steam ships, especially with reference to the comparative Cost at which freight would, on the assumed data, be conveyed at different rates of *speed* on passages of given length, the following Tables (Series No. 2) have been constructed for vessels varying from 500 to 10,000 tons of mean displacement, and employed on passages of 500, 1000, 2000, 3000, 4500, and 6000 nautical miles, at rates of speed from 6 to 20 nautical miles an hour. These calculations, like those in the foregoing Tables are based on the assumption that the weight of the hull and equipment, exclusive of the engines, will appropriate 40 per cent. of the mean displacement ; that the weight of the engines in complete working order will be one ton per H.P., and the consumption of fuel 4 cwts. per H.P. per day : the UNIT of power (H.P.) being taken at 132'000 lbs. raised one foot per minute.

Calculated for the mean DISPLACEMENT of 1250 TONS. Index Number 862, and H.P. = $\frac{P.V.}{183'000}$.

[illegible]

SERIES 2.—TABLE No. 13.

Calculated for the mean Displacement of 10,000 TONS. Index Number 871, and H.P. = $\frac{P.Y.}{132.000}$.

SPEED—PER HOUR.	HORSE-POWER.		WEIGHT OF HULL AND ENGINES.		PASSAGE 500 NAUTICAL MILES.			PASSAGE 1000 NAUTICAL MILES.			PASSAGE 2000 NAUTICAL MILES.			PASSAGE 3000 NAUTICAL MILES.			PASSAGE 4500 NAUTICAL MILES.			PASSAGE 6000 NAUTICAL MILES.		
	N.M.	H.P.	TONS.	D. H.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.	Time.	Coal.	Cargo.
6	6	116	4116	3-11	80	5843	6-23	161	5803	13-21	322	5722	20-20	483	5642	31-6	725	5521	41-16	966	5400	
7	7	184	4184	2-23	109	5761	5-23	219	5706	11-22	438	5596	17-21	657	5497	26-19	985	5323	35-17	1314	5158	
8	8	276	4276	2-14	143	5652	5-5	287	5580	10-10	575	5436	15-15	862	5292	23-10	1293	5077	31-6	1725	4861	
9	9	388	4388	2-8	179	5522	4-15	359	5432	9-6	718	5252	13-21	1077	5073	20-20	1616	4803	27-19	2155	4584	
10	10	536	4536	2-2	223	5352	4-4	446	5240	8-8	893	5017	12-12	1340	4794	18-18	2010	4459	25-0	2680	4124	
11	11	712	4712	1-21	269	5153	3-19	539	5018	7-14	1073	4748	11-9	1618	4478	17-1	2427	4074	22-17	3236	3669	
12	12	923	4923	1-18	322	4910	3-11	644	4749	6-23	1288	4427	10-10	1933	4105	15-15	2900	3622	20-20	3866	3138	
13	13	1180	5180	1-14	378	4630	3-5	756	4441	6-10	1512	4063	9-15	2269	3685	14-10	3403	3118	19-6	4388	2550	
14	14	1472	5472	1-12	438	4308	2-23	876	4089	5-23	1752	3651	8-22	2628	3213	13-9	3942	2556	17-21	5257	1899	
15	15	1812	5812	1-9	503	3936	2-19	1006	3684	5-13	2013	3181	8-8	3020	2678	12-12	4530	1923	16-16	6040	1168	
16	16	2200	6200	1-7	572	3513	2-14	1145	3226	5-5	2291	2653	7-19	3437	2081	11-17	5156	1221	15-15	6875	362	
17	17	2636	6636	1-5	646	3040	2-11	1232	2717	4-22	2584	2071	7-8	3876	1425	11-1	5814	456				
18	18	3132	7132	1-4	725	2505	2-8	1450	2143	4-15	2900	1418	6-23	4350	693							
19	19	3684	7684	1-2	807	1912	2-5	1615	1508	4-9	3231	700										
20	20	4296	8296	1-1	895	1256	2-2	1790	809													

It has been previously observed that the larger the vessel the greater will be its capabilities in proportion to the power employed; but, constant employment and full freight are indispensable to this condition in favor of large vessels, and the limitations of mercantile Investment, Insurance, and Harbour accommodation all tend to restrict the size of vessel that might otherwise be most advantageously employed. It is, therefore, purposed to illustrate the mutual relations of SPEED and COST by assuming, for example, the employment of a vessel of large size, say 5000 tons' mean displacement (being about 4140 tonnage builders' measurement), and ascertaining, in the first place, the *proportional* scale of cost that will be incurred in the conveyance of cargo *per ton* at different rates of speed and on passages of various length, say 1000, 3000, and 6000 nautical miles.

Now suppose, for example, that the passage be 1000 miles, and that, for brevity, we confine our remarks to the engine department only; which, indeed, will be the department of expense, chiefly affected by variations in the rate of speed. By reference to Table No. 10, it appears that the vessel of 5000 tons' mean displacement, if fitted to run at the speed of EIGHT NAUTICAL MILES per hour, will require 172 H.P., and a cargo of 2738 tons will be conveyed 1000 miles in five days five hours; being equivalent to one day's employment of $\frac{88}{100}$ H.P. *per ton* of goods.

If fitted to run at TEN NAUTICAL MILES an hour, the vessel will require 336 H.P., the cargo will be reduced to 2524 tons, and the time to four days four hours; being equivalent to one day's employment of $\frac{55}{100}$ H.P. *per ton* of goods nearly.

If fitted to run at TWELVE NAUTICAL MILES an hour, the vessel will require 581 H.P., the cargo will be reduced

to 2217 tons, and the time to three days eleven hours ; being equivalent to one day's employment of $\frac{91}{100}$ H.P. *per ton of goods*.

If fitted to run at FOURTEEN MILES an hour, the vessel will require 923 H.P., the cargo will be reduced to 1802 tons, and the time to two days twenty-three hours ; being equivalent to one day's employment of $1\frac{52}{100}$ H.P. *per ton of goods*.

If fitted to run at SIXTEEN MILES per hour, the vessel will require 1377 H.P., the cargo will be reduced to 1264 tons, and the time to two days fourteen hours ; being equivalent to one day's employment of $2\frac{86}{100}$ H.P. *per ton of goods*.

If fitted to run at EIGHTEEN MILES per hour, the vessel will require 1961 H.P., the cargo will be reduced to 585 tons, and the time to two days eight hours ; being equivalent to one day's employment of $7\frac{75}{100}$ H.P. *per ton of goods*.

And if fitted to run at TWENTY MILES per hour, there will be no displacement available for mercantile cargo.

Assuming, now, that the cost per ton of goods will be in proportion to the amount of power and tonnage employed to do the work, it appears that the cost *per ton of goods* of performing this passage of 1000 miles, at the respective speeds of 8, 10, 12, 14, 16, and 18 miles, will be proportional to the numbers— $\frac{88}{100}$, $\frac{55}{100}$, $\frac{91}{100}$, $1\frac{52}{100}$, $2\frac{86}{100}$, and $7\frac{75}{100}$ which are proportional to the numbers 33, 55, 91, 152, 286, and 775, or nearly as 1, 2, 3, 5, 9, and 23.

Hence, it appears, that in the case of the ONE THOUSAND MILES passage above referred to, the cost of freight *per ton of goods* at TEN MILES per hour, will require to be nearly the *double* of the rate at EIGHT MILES per hour.

The cost per ton at TWELVE MILES per hour will require to be *three times* the rate at EIGHT MILES.

The cost per ton at FOURTEEN MILES per hour will require to be *five times* the rate at EIGHT MILES.

The cost per ton at SIXTEEN MILES per hour will require to be *nine times* the rate at EIGHT MILES.

The cost per ton at EIGHTEEN MILES per hour will require to be *twenty-three times* the rate at EIGHT MILES.

And at TWENTY MILES per hour there will be *no displacement* available for mercantile cargo.

By applying the same process of calculation to a ship of 5000 tons' mean displacement, making a passage of THREE THOUSAND MILES, we shall find that, at TEN MILES an hour, the cost of freight per ton will require to be double the rate of freight at EIGHT MILES.

The cost per ton at TWELVE MILES will require to be three times the rate at EIGHT MILES.

The cost per ton at FOURTEEN MILES will require to be six times the rate at EIGHT MILES.

The cost per ton at SIXTEEN MILES will require to be twenty times the rate at EIGHT MILES.

And at EIGHTEEN MILES per hour there will be *no displacement* available for mercantile cargo.

Finally, by applying the same process of calculation to a ship of 5000 tons' mean displacement on a passage of 6000 miles, it will be found that the cost of freight per ton at TEN MILES per hour will require to be *double* the rate at EIGHT MILES.

The cost per ton at TWELVE MILES per hour will require to be about *five times* the rate at EIGHT MILES.

The cost per ton at FOURTEEN MILES per hour will be about *sixteen times* the rate at EIGHT MILES.

And at SIXTEEN MILES per hour there will be *no displacement* available for mercantile cargo.

Hence, it appears, that for voyages of 1000 miles and upwards, without re-coaling, the speed of ten nautical miles per hour would involve about *double* the cost *per ton* of eight miles, and may, therefore, be regarded as the extreme limit that can be generally entertained for the mercantile purpose of goods' conveyance; and that the attainment on long passages of a higher rate of speed than ten miles (though admissibly practicable) would involve obligations altogether of an exceptional character, such as the special service of despatches, mails, passengers, specie, and the most valuable description of goods can only meet.

It now appears desirable to arrive at some approximately *definite* view of the extent to which the cost of the conveyance of cargo is cheapened, according as the work may be done by vessels of increased magnitude, for example:—1250, 2500, and 5000 tons' mean displacement.

By Table No. 4, at eight miles per hour, a ship of 1250 tons' displacement, with 69 H.P., will convey 465 tons of cargo on a passage of 6000 miles in thirty-one days six hours, being equivalent to one days' employment of 84 tons of shipping and $4\frac{6}{10}$ H.P. *per ton* of goods.

By Table No. 7, at eight miles per hour, a ship of 2500 tons' displacement and 109 H.P. will convey 1050 tons of cargo the same distance (6000 miles) in the same time, viz., thirty-one days six hours; being equivalent to one day's employment of 74 tons of shipping and $3\frac{2}{10}$ H.P. *per ton* of goods.

By Table No. 10, at eight miles per hour, a ship of 5000 tons' displacement and 172 H.P. will convey 2290 tons of cargo the same distance (6000 miles) in the same time; being equivalent to one day's work of 68 tons of shipping and $2\frac{8}{10}$ H.P. *per ton* of goods.

It appears, therefore, that in the SHIPPING department the *reduction* of cost per ton of cargo, consequent on the *increasing* size of the SHIP, namely, 1250, 2500, and 5000 tons of mean displacement, will be in the proportion of 84, 74, and 68, which numbers are in the proportion of 100, 88, and 81, and in the ENGINE department, the reduction of cost per ton of cargo will be in proportion to the numbers $4\frac{6}{10}$, $3\frac{2}{10}$, and $2\frac{8}{10}$, which numbers are in the proportion of 100, 70, and 50.

Hence, in the case under consideration, namely, a passage of 6000 miles, steaming at the mean speed of eight miles per hour, by increasing the size of the ship from 1250 to 5000 tons of mean displacement, the reduction of cost per ton of cargo amounts in the shipping department to 19 per cent., and in the engine department to 50 per cent. If, moreover, the size of the ship be further extended from 5000 tons of mean displacement to the unprecedented size of 10,000 tons, the rate of freight in the shipping department will be further reduced about 8 per cent., and in the engine department the reduction will be about 20 per cent. It may, however, be observed that this source of commercial economy in favor of the ship of the unprecedented size of 10,000 tons' displacement will again be altogether sacrificed if, on the strength of it, we attempt to run the ship of 10,000 tons' mean displacement at *nine miles* per hour in competition with ships of 5000 tons' mean displacement running at *eight miles* per hour, and carrying, on the aggregate, the same quantity of goods.

In all the foregoing Tables the speed has been calculated with reference to the STEAM-POWER alone, on which the *regularity* of steam-ship voyages will be mainly dependent: the influence of the wind may, in fact, be regarded as an obstruction to the *regular* attainment of high speed; for, a

favorable wind, though helping a vessel when steaming at the speed of *eight* nautical miles per hour, may afford no aid, or even *oppose* the vessel, when steaming at *twelve* miles per hour ; and, an adverse wind will obstruct the vessel, if steaming at high speed, in a far greater ratio than it would the low speed ship.

It is, therefore, presumed to have been sufficiently shown by the foregoing calculations and deductions therefrom (though avowedly based on approximate data), that extreme caution ought to attend all mercantile contracts in regard to the obligation of maintaining such a rate of speed for a *long passage* as exceeds the rate at which the wind may be expected to partially co-operate with the steam-power ; it is also presumed to have been shown how greatly it is to be apprehended that various projects, now publicly promulgated, and confidently professing to undertake the regular performance of very long passages at high rates of speed, (for instance, fifteen nautical miles per hour and upwards) are based on expectations not commercially justified by the relation which, at present, actually subsists between steamship displacement, power, speed, and cost of freight *per ton* ; at least, if the probability of the due fulfilment of such projects is to be judged of by the locomotive capability that has, hitherto, been practically realized by the most successful steam-vessels of the present day.

SECTION V.

INVESTIGATION AS TO THE COMPARATIVE EXTENT TO WHICH THE COST OF FREIGHT PER TON IS AFFECTED BY DIFFERENCES OF ORIGINAL CONSTRUCTION AS REGARDS THE LOCOMOTIVE PROPERTIES OF DIFFERENT SHIPS, OR BY DIFFERENT DEGREES OF FALLING OFF IN THE WORKING CONDITION OF THE HULL, ENGINES, AND BOILERS OF THE SAME SHIP.

THE previous Sections constitute an example of a system of calculation whereby the mercantile CAPABILITIES of a ship and the mutual relation of Speed and Cost may be approximately determined. It is now proposed, by an analogous system of investigation, to deduce an approximate estimate of the commercial advantage in regard to the cost of freight per ton that attends the employment of ships *suitably* constructed for the service on which they may be employed, as compared with vessels of *inferior* adaptation. By this investigation the comparative financial balance of outlay and income, which may be expected of any one vessel as compared with another, may be equitably apportioned, the determination of which issue will, it is conceived, greatly conduce to the effective DIRECTION and MANAGEMENT of mercantile steam shipping, not only in matters of financial economy, but also in so far that on a vessel failing to fulfil an assigned service, a line of discrimi-

nation may be drawn as to the degree in which such failure may be attributable to faults of original construction, producing a low scale of locomotive efficiency, or to defective measures in matters of direction, or of personal management and command. Moreover, steam-ship proprietors will thus be enabled to determine the relative value of their stock, not indeed as respects the intrinsic value of the respective ships, but as respects their relative working properties and consequent value for any special service. Each vessel may thus be assigned to its most appropriate duty, and vessels manifestly of an unsuitable adaptation for one Line of Trade may be otherwise employed or disposed of, instead of being put upon services which they are thus *constructively* inadequate to perform: for example, a vessel may be well adapted for the economical conveyance of cargo at eight miles per hour, but by being employed upon a service demanding a higher rate of speed, and failing, the ship is held to be inefficient, the stock becomes unduly depreciated, and incapacity of DIRECTION, the real cause of the failure, escapes unobserved. With a view, therefore, to compare the mercantile results to be fairly expected of steam vessels under different conditions of locomotive efficiency, the following Table (G) has been arranged to shew, in juxtaposition, the extent to which the power (H.P.) is affected by the different degrees of SCIENTIFIC SKILL with which different vessels may have been *originally* constructed, or by various degrees of *falling off*, as regards working condition, to which the hull and machinery of steam ships is liable. The relative degrees of efficiency being indicated by the index numbers, 862, 792, 664, and 602, assumed as the base of the calculation by way of example, and the UNIT of power (H.P.) being taken as equivalent to 132,000 lbs., raised one foot per minute, as in all the previous calculations.

TABLE G.

SPEED PER HOUR.		INDEX NUMBERS.	DISPLACEMENT IN TONS.													
			500	750	1000	1250	1500	2000	2500	3000	4000	5000	6000	8000	10,000	
N. M.			H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	
6	{	862	16	20	25	29	33	40	46	52	64	73	83	100	116	
		792	17	23	27	32	36	43	50	57	69	80	90	109	127	
		664	21	27	33	38	43	52	60	68	82	95	108	130	151	
		602	23	30	36	41	47	57	66	75	90	105	118	143	166	
7	{	862	25	32	40	46	52	63	73	83	100	115	131	159	184	
		792	27	36	43	50	57	69	80	90	109	127	143	174	201	
		664	33	43	52	60	68	82	95	108	130	151	171	207	240	
		602	36	47	57	66	75	90	105	118	143	166	188	227	264	
8	{	862	37	49	59	69	78	94	109	123	148	172	196	237	276	
		792	41	53	65	75	85	103	119	135	163	189	214	259	300	
		664	49	64	77	90	101	123	142	161	195	226	255	309	359	
		602	54	70	85	98	111	135	156	177	214	248	281	340	394	
9	{	862	53	70	84	97	111	134	155	175	212	245	279	338	388	
		792	58	76	92	107	121	146	170	192	232	270	304	369	428	
		664	69	91	110	128	144	175	203	229	277	322	363	440	511	
		602	76	100	121	140	159	192	223	252	305	354	400	484	562	
10	{	862	73	96	116	134	152	184	213	241	292	336	383	463	536	
		792	79	104	127	147	166	201	233	263	319	370	418	506	587	
		664	95	125	151	175	198	240	278	314	380	441	498	604	700	
		602	105	137	166	192	217	264	306	345	418	485	548	664	771	
11	{	862	97	127	154	178	202	245	284	320	388	448	510	616	712	
		792	106	139	168	195	221	267	310	350	424	492	556	673	781	
		664	127	166	201	233	263	319	370	418	506	587	663	804	932	
		602	139	182	221	256	289	351	407	459	557	646	730	884	1026	
12	{	862	126	165	200	232	262	317	368	416	504	581	660	800	928	
		792	138	180	219	254	286	347	402	455	551	639	722	874	1014	
		664	164	215	261	303	342	414	480	542	657	762	861	1043	1210	
		602	181	237	287	333	376	455	528	596	722	838	947	1148	1331	
13	{	862	160	210	254	295	333	403	468	529	640	739	840	1017	1180	
		792	175	229	278	322	364	441	512	578	700	812	917	1111	1289	
		664	209	274	332	385	434	526	610	690	835	969	1094	1326	1539	
		602	230	301	365	423	478	579	672	758	919	1067	1205	1459	1693	
14	{	862	200	262	317	368	416	504	585	661	800	923	1049	1270	1472	
		792	219	286	347	403	455	551	639	722	874	1014	1146	1388	1611	
		664	261	342	414	481	543	657	763	861	1043	1211	1367	1656	1922	
		602	287	376	456	529	597	723	839	947	1147	1332	1504	1823	2115	
15	{	862	246	322	390	453	512	620	720	813	984	1135	1291	1562	1812	
		792	269	352	427	495	559	678	786	888	1075	1248	1409	1707	1982	
		664	321	420	509	591	667	809	938	1059	1283	1489	1682	2037	2364	
		602	353	463	560	650	735	890	1033	1165	1411	1639	1851	2242	2602	
16	{	862	299	391	474	550	621	753	873	987	1196	1377	1567	1897	2200	
		792	326	427	518	601	679	822	954	1077	1305	1515	1710	2072	2405	
		664	389	510	618	717	810	981	1138	1286	1558	1807	2041	2473	2869	
		602	429	561	680	789	892	1080	1253	1414	1712	1989	2246	2721	3158	

The foregoing Table (G) shows, in juxtaposition, the gradually *increasing* power that is required to propel vessels of given displacement, at a given speed, according to the gradually *decreasing* locomotive efficiency of the vessels as indicated by the index numbers, 862, 792, 664, and 602 respectively ; which numbers have been preferred for illustration as being the index numbers of vessels of a known type of construction, previously referred to in Statement No. 2, page 11, and for which the mutual relations of Displacement, Power, and Speed have been partially calculated in Tables A, B, C, D. The results, as regards the all-important item of POWER being thus brought into comparison, the exposition shows not merely the *differences* of power that vessels of the *same displacement*, but of the *different types* referred to, would require, if employed on a station demanding a given rate of speed, but also the different degrees of power to which the machinery of a *given ship* will require to be *forced* (for marine engines and boilers may be expressly adapted for being capable of exerting a power beyond the limit assigned for their ordinary and constant work,) according as the locomotive properties of the vessel may have *fallen off* by reason of foul bottom, defective machinery, neglectful management, bad stowage, or other cause. These liabilities to falling off in the condition of ships, indicate the expediency of all steam vessels being supplied with boiler-power in excess of the power absolutely required for performing the service for which the vessel may have been constructed ; and, as in any ship when in its best condition, at a given draught or displacement, the rate of speed corresponding to a given amount of working power should be always known, it follows that any material falling off of speed will indicate the existence of defect, either to be remedied or else otherwise met by compensating measures, such for instance, as

an increased supply of coal to the *sacrifice of cargo*, and working the engines up to greater power, in order that the vessel may still keep time.

For example, referring to Table G, take a vessel of 3000 tons' displacement, of which the ascertained index number may have been 862, this vessel, if in good condition, may be expected to run at *ten* nautical miles per hour, with 241 H.P. ; if, however, we find on test-trial that the speed has *fallen off* to *nine* miles per hour with the engines working at 229 H.P., the index number of the ship in this condition will then be 664, and her continued employment on the *ten* mile service will require (according to Table G) that the working power be forced up to 314 H.P.—being 73 H.P. beyond the original requirement for the *ten* mile speed. If, now, the boilers on board will not supply the required quantity of steam for this additional 73 H.P. being developed by the engines, the vessel will be unfit for the service in question, but if the boilers will afford the required quantity of steam, and the engines be fit to use it, then the *ten* mile service will still be practicable, but the extra cost of running the vessel in this defective condition will be not only the cost of the extra quantity of fuel that will be consumed, corresponding to the extra power now required, but the displacement available for freight will also be reduced, thereby enhancing the cost of freight *per ton* in a compound ratio ; and it is now purposed to investigate, approximately, the *proportional extent* to which the cost of freight *per ton* will be thus enhanced in consequence of such defective condition of the vessel ; to facilitate this enquiry the following Table (H) has been compiled, showing the extent to which the displacement *available for cargo* is affected by differences of CONSTRUCTIVE MERIT, as indicated by the *differences* of index number at which the vessel may be classed.

TABLE H.

Showing the extent to which the DISPLACEMENT available for CARGO is affected by differences of steam-ship CONSTRUCTIVE MERIT or WORKING CONDITION, as indicated by variations of the Index Number at which the vessel may be classed.

MEAN DISPLACEMENT AND LENGTH OF PASSAGE.	SPEED PER HOUR	TIME OF PASSAGE.	INDEX NUMBER, 862.			INDEX NUMBER, 792.			INDEX NUMBER, 664.			INDEX NUMBER, 602.		
			POWER.	COAL.	CARGO.	POWER.	COAL.	CARGO.	POWER.	COAL.	CARGO.	POWER.	COAL.	CARGO.
			H. P.	TONS.	TONS.	H. P.	TONS.	TONS.	H. P.	TONS.	TONS.	H. P.	TONS.	TONS.
DISPLACEMENT, .. 3000 TONS ; PASSAGE, ... 3000 MILES.	N. M.	D. H.	8	128	384	1485	135	422	1454	161	503	1387	177	553
	9	15-15	175	486	1882	192	533	1841	229	636	1253	252	700	1198
	10	18-21	241	602	1268	263	657	1208	314	785	1093	345	862	1024
	11	12-12	320	727	1116	350	795	1052	418	950	907	459	1043	819
DISPLACEMENT, .. 4000 TONS ; PASSAGE, ... 4500 MILES.	12	11-9	416	867	951	455	948	871	542	1129	698	596	1242	583
	8	10-10	148	694	1905	163	764	1855	195	914	1748	214	1003	1684
	9	23-10	212	883	1746	232	967	1686	277	1154	1546	305	1271	1460
	10	20-20	292	1095	1560	319	1196	1483	380	1425	1307	418	1567	1198
DISPLACEMENT, .. 5000 TONS ; PASSAGE, ... 6000 MILES.	11	18-18	388	1323	1351	424	1445	1253	506	1795	1081	557	1899	894
	12	17-1	504	1575	1108	551	1722	988	657	2053	716	722	2256	550
	8	15-15	172	1075	2291	189	1181	2220	226	1412	2068	248	1550	1977
	9	31-6	245	1361	2074	270	1500	1980	322	1789	1784	354	1967	1663
DISPLACEMENT, .. 6000 TONS ; PASSAGE, ... 6000 MILES.	10	27-19	336	1680	1824	370	1830	1705	441	2305	1457	485	2425	1308
	11	25-0	448	2036	1534	492	2236	1390	587	2668	1079	646	2936	886
	12	22-17	581	2421	1209	639	2662	1030	762	3175	651	838	3492	416
	8	20-20	148	694	1905	163	764	1855	195	914	1748	214	1003	1684

Referring to the foregoing Table (H) it appears that a ship of 3000 tons' mean displacement, of which the index number is 862, will be propelled at ten nautical miles per hour, by 241 H.P., and that a passage of 3000 nautical miles will be performed in twelve days twelve hours, conveying 1258 tons of cargo, being equivalent to one day's work of $29\frac{5}{8}$ tons of shipping, and one day's work of $2\frac{7}{18}$ H.P. per ton of goods.

But if the index number of the vessel be reduced to 602, it appears that 345 H.P. will be required to attain the speed of ten nautical miles per hour, and the cargo will be reduced to 1024 tons, being equivalent to one day's work of $36\frac{3}{8}$ tons of shipping, and one day's work of $4\frac{2}{9}$ H.P. per ton of goods. Now, supposing the *cost* of freight to be proportional in the SHIPPING department to the amount of *tonnage*, and in the ENGINE department to the amount of *engine power* (H.P.) employed for a given time to do the work, it follows that the cost per ton of cargo on the passage referred to will be enhanced in the SHIPPING department proportionally to the numbers $29\frac{5}{8}$ and $36\frac{3}{8}$, or as 100 to 123, or 23 per cent., and in the ENGINE department proportionally to the numbers $2\frac{7}{18}$ and $4\frac{2}{9}$ or as 100 to 176, or 76 per cent.; on the whole, therefore, the cost of freight *per ton* will be enhanced probably about 50 per cent., or about the mean per centage of the two departments.

By the same process of investigation it will be found that with a vessel of 4000 tons' mean displacement, making a passage of 4500 nautical miles, at the rate of ten miles per hour, a reduction of the index number from 862 to 602 will enhance the cost of freight *per ton* about 60 per cent.; and, with a vessel of 5000 tons' mean displacement, making a passage of 6000 nautical miles, at the rate of ten miles per hour, a reduction of the index number from 862 to 602 will enhance the cost of freight *per ton* about 70 per cent.

The extent of variation, assumed in the above cases, in the *index numbers* of the vessels supposed to be employed, or this assumed extent of *falling off* in the index number of the same vessel under different conditions of efficiency, namely, a falling off from 862 to 602, in consequence whereof the cost of freight per ton on the passages referred to has been so greatly enhanced, viz.—50 per cent. on the 3000 mile passage ; 60 per cent. on the 4500 mile passage ; and 70 per cent. on the 6000 mile passage, is by no means an extreme case of variation, but such, as judging from experience, is likely to be of common occurrence, for on comparison of vessels of analogous class, and of which the length exceeds five times the breadth, the index numbers have been found to vary 30 per cent. and upwards, and it has been found that the index number of the same vessel, but in different conditions of efficiency, is liable to vary fully 20 per cent.

It now remains to be observed that in all the foregoing calculations the consumption of fuel per H.P. has been presumed to be constant, viz., at the rate of 4 cwt. per H.P. per day of 24 hours, the unit of power (H.P.) being taken at 132·000 lbs., raised 1 foot per minute, that is about 18 lbs. of coal per hour for each 132·000 lbs., moving 1 foot per minute, or $4\frac{1}{2}$ lbs. per hour for each 33,000 lbs., moving 1 foot per minute, which rate of consumption is not generally realized in present marine engine practice, or, at least, it requires the boilers, and their management, to be of the first-rate order. It is, however, to be expected not only that improvement in boiler construction productive of greater economy of fuel, in proportion to the water evaporated, will be effected ; but also that improved methods of applying the steam, or improved systems of working it, whereby a greater amount of power (H.P.) may be derived from a given

amount of evaporation, will be introduced in marine navigation ; and, on the other hand, *impaired* efficiency in the boiler department of steam-ships, whereby the consumption of fuel becomes *increased*, is liable to occur. No definite limit can be assigned to such fluctuations ; but, assuming them at 25 per cent. only, the consumption of coal per H.P., under different circumstances of engine and boiler construction, condition, and management, may be expected to fluctuate from 3 cwt. per H.P. per day to 5 cwt. per H.P. per day. Accordingly, the following Table (I) has been arranged and calculated for ships of 4000 tons' mean displacement employed on a passage of 4500 nautical miles,—the consumption of fuel being assumed, according to the construction or condition of the machinery, at 3 cwt., 4 cwt., and 5 cwt. per H.P. per day ; and the index numbers, representing the locomotive efficiency of the vessels, being assumed at 862, 664, and 602, which, as before stated, are not extreme cases of fluctuation. The object of the whole investigation is to arrive at some general appreciation of the *extent* to which the cost of goods transport is affected by *differences* in the CONSTRUCTIVE MERIT of the steam-ship Stock ; and the calculation is based on the assumption that the cost of goods transport *per ton* is approximately proportional to the amount of tonnage, and the amount of engine power employed for a given time to do the work.

TABLE I.
MEAN DISPLACEMENT, 4000 TONS; PASSAGE, 4500 NAUTICAL MILES.
Showing the commercial effect on the cost of Freight per Ton, occasioned by differences in the original construction or subsequent working condition of the Hull, Engines, and Boilers.

CONSUMPTION OF COAL PER H.P. PER DAY OF 24 HOURS.	SPEED—PER HOUR.		TIME OF PASSAGE		INDEX NUMBER, 862.				INDEX NUMBER, 664.				INDEX NUMBER, 602.				
	N. M.	D. H.	H. P.	TONS.	TONS.	Cost of Cargo, proportional to 1 day's employment per ton of freight of		H. P.	TONS.	TONS.	Cost of Cargo, proportional to 1 day's employment per ton of freight of	H. P.	TONS.	TONS.	Cost of Cargo, proportional to 1 day's employment per ton of freight of		
						Power.	Coal.									Cargo.	Power.
3 Cwts. PER H.P. PER DAY.	6	31·6	64	300	2186	57	0·91	82	384	2126	59	1·21	90	422	2099	60	1·84
	7	26·19	100	402	2099	51	1·23	130	522	2009	53	1·73	143	575	1970	54	1·94
	8	23·10	148	520	1992	47	1·74	195	686	1862	50	2·46	214	752	1810	52	2·77
	9	20·20	212	662	1857	45	2·38	277	866	1690	49	3·41	305	953	1618	52	3·93
	10	18·18	292	821	1698	44	3·23	380	1069	1486	50	4·79	418	1176	1394	54	5·62
4 Cwts. PER H.P. PER DAY.	6	31·6	64	400	2136	59	0·94	82	512	2062	61	1·24	90	562	2029	62	1·89
	7	26·19	100	536	2032	53	1·32	130	696	1922	56	1·81	143	766	1874	57	2·04
	8	23·10	148	694	1905	49	1·82	195	914	1748	54	2·61	214	1003	1684	56	2·98
	9	20·20	212	888	1746	48	2·53	277	1154	1546	54	3·73	305	1271	1460	57	4·35
	10	18·18	292	1095	1560	48	3·51	380	1425	1307	57	5·45	418	1567	1198	63	6·54
5 Cwts. PER H.P. PER DAY.	6	31·6	64	500	2086	60	0·96	82	641	1998	63	1·28	90	708	1958	64	1·44
	7	26·19	100	670	1965	55	1·36	130	871	1835	58	1·90	143	958	1778	60	2·15
	8	23·10	148	867	1818	52	1·91	195	1143	1634	57	2·80	214	1254	1569	60	3·22
	9	20·20	212	1104	1636	51	2·70	277	1443	1402	59	4·12	305	1589	1301	64	4·88
	10	18·18	292	1369	1424	53	3·84	380	1781	1180	66	6·30	418	1959	1002	75	7·82

From this Table (I) we arrive at the following conclusions :—1st. That a ship of 4000 tons' mean displacement, of which the INDEX NUMBER is 862 and consumption of FUEL 3 cwt. per H.P. per day, will make a passage of 4500 nautical miles, at the speed of ten miles per hour, by one day's employment of 44 tons of shipping and $3\frac{23}{100}$ H.P. per ton of freight ; but, if the INDEX NUMBER be reduced to 664, and the consumption of fuel be increased to 4 cwt. per H.P. per day, the passage will be made by the employment of Tonnage and Power equivalent to one day's employment of 57 tons of Shipping and $5\frac{45}{100}$ H.P. per ton of freight : that is, the cost of freight will be enhanced in the Shipping department in the proportion of 44 to 57, or 100 to 130 or about 30 per cent. ; and in the Engine department in the proportion of $3\frac{23}{100}$ to $5\frac{45}{100}$, or as 323 to 545, or 100 to 170, or about 70 per cent. : that is, taking the mean per centage of the two departments, the cost of freight per ton will be enhanced about 50 per cent. in consequence of the above-mentioned *inferiority* in the original construction or subsequent *falling off* in the working condition of the ship employed.

Again, if the index number of the vessel be reduced from 862 to 602, and the consumption of fuel increased from 3 cwt. to 5 cwt. per H.P. per day, it will appear by a similar process of calculation to that above-exemplified, that the cost of freight *per ton* will be enhanced about 100 per cent., or doubled, in consequence of such inferiority of original construction, or subsequent falling off in the working condition of the ship employed.

It may further be observed that the *inferior* ship above-mentioned, if fitted to run at *eight miles* per hour,

would convey freight at about the *same scale* of cost as would be effected by the *superior* ship if running at *ten miles* per hour, though, as above shown, incurring *double* the cost per ton of goods conveyed, if running at the same speed. Hence we may infer the advantage that would accrue to steam-ship companies from having a variety of service on which to employ their stock, demanding different rates of speed, according to the unavoidable differences of their respective ships.

The foregoing examples as to the difference of cost *per ton* of freight, at which the same service, at a given rate of speed, would be performed by different vessels, or by the same vessel under different conditions of efficiency, sufficiently demonstrate that the comparative CONSTRUCTIVE MERIT of new ships and the upholding of STOCK ships in their most perfect condition, are points of management in steam-ship DIRECTION vitally affecting the commercial prosperity of any steam-ship enterprise, and constitute considerations, under which the subject-matter of the foregoing exposition assumes an important bearing, not merely on private, but even on national interests, dependant as the interests of all Commercial Nations now are on ocean navigation,—an issue pointing out the necessity for adopting *some* recognised method of calculation and STANDARD MEASURE of *comparison* whereby the relative constructive merit of steam-ships may be satisfactorily determined, and whereby the FAME which may justly attach to pre-eminence in the nationally-important art of STEAM-SHIP CONSTRUCTION may be justly awarded where, and where only, such credit may be justly due.

SUPPLEMENT

IN CONTINUATION OF

STEAM SHIP CAPABILITY.

Mr. ATHERTON avails himself of the publication of the second issue of the foregoing Essay to extend his work, and partially correct its deficiencies, in accordance with the suggestions which have been brought before his notice. For instance, it has occurred to Mr. A. that the express object of Table I (Page 70) would be more effectually attained and appreciated if the results, instead of being represented by proportional numbers, were worked out to show the actual COST EXPENSES of freight per ton of cargo conveyed. To effect this object Mr. A. has assumed certain arbitrary, but, as he is advised, usual, details of prime cost estimate, by which he has extended the calculations to shew the prime cost expenses incidental to the conveyance of cargo per ton weight of cargo conveyed, applying this system of calculation to a ship of 2,500 tons employed on the service of a 3,250 miles passage, as exemplified by Table K. Also, as recently projected schemes and actual engagements in steam-ship construction far exceed the limits of Displacement embodied in the foregoing Tables it has been considered advisable to extend the Tables to embrace the consideration of vessels of *hypothetical* MAGNITUDE; accordingly, a further series of Tables is now presented, shewing, theoretically, by induction, what may be expected to be the capabilities of such vessels. In these speculations Mr. A. has confined himself to the consideration of the probable dynamic capabilities of the vessels, not doubting the efficiency of their practical construction, and without reference to the Mercantile management, or the Statistical and Nautical

considerations by which the practical operation of such vessels must be affected.

It has been objected that the consumption of coal, on which the Tables have been calculated is higher than usual in present marine engine practice; but it appears that such objectors have based their own calculations on the *reputed* nominal power of their engines, without reference to the Indicated h.p., or to any *definite* measure of their working power, and have failed to afford conclusive evidence of any Mercantile Steam-ship service being performed at a less average rate of consumption than 18lbs. per hour per H.P., of 132,000 raised 1 foot per minute, or $4\frac{1}{2}$ lbs. per Indicated h.p. of 33,000lbs. raised 1 foot per minute. Mr. A. admits the possibility, and therefore the probability, of this rate of consumption being reduced, and he has endeavoured to elucidate the effect of such reduction in the following pages.

It has also been suggested that the Tables would have been more explicit had they been based on the unit of power, denoted Indicated h.p. of 33,000lbs. raised 1 foot per minute, rather than on the H.P. deduced from the actual performance of the 10 Mail-packets referred to at page 5, giving the unit of power (H.P.) as equivalent to 132,000lbs. raised 1 foot per minute. Mr. A. has therefore, in the following statements, made more express reference to the unit of 33,000lbs, raised 1 foot per minnte, denoting it thus—Indicated h.p.; and his views as to the necessity of some UNIT of power being *specified* and *legalized* as the standard measure of power, denoted by the term H.P., is set forth in the appendix letters, Nos. 1 and 2.

Further, Mr. A. feels it but due to himself to observe that some parties have evinced a misapprehension of the sentiments advanced by him, and of the limitation of the premises on which certain results have been deduced,

and conclusions thus based on special cases of steam-ship application have been erroneously quoted as the generalised opinions of the Author. Mr. A. has therefore published in the APPENDIX hereto an almost literal copy of the written statements addressed by him to the Institution of Civil Engineers, London, on this subject, the purport of which is so closely connected with, and explanatory of, the matters under consideration as to justify the otherwise objectionable introduction of such collateral dissertation.

Conformably with the foregoing suggestions we now resume the subject of Chapter 5, by shewing approximately on *assumed* data as to the detail of cost, the pecuniary prime cost EXPENSES of freight per ton of cargo conveyed, under certain conditions as to the size and QUALITY of the ship, length of passage, and steaming speed. Accordingly, the following Table K has been arranged and calculated for ships of 2,500 tons mean or Mid-passage Displacement employed on a passage of 3,250 nautical miles, and fitted to steam at the speeds of 8, 10, and 12 knots an hour, the Index numbers denoting the different degrees of dynamic QUALITY of the respective vessels, (calculated by the formula $\frac{v^3}{\text{H.P.}} = C$ and unit of power before referred to,) being assumed at 1000, 862, and 664, and the consumption of fuel according to the possibly variable construction or condition of the boilers and machinery being also assumed at the respective rates of 12lbs., 16lbs., and 20lbs. per hour, per H.P. of 132,000lbs., raised 1 foot per minute, or 3lbs., 4lbs., and 5lbs. per hour, per Indicated h.p. of 33,000lbs., raised 1 foot per minute. The object of this investigation is to arrive at some definite estimate of the extent to which the pecuniary prime cost EXPENSE of goods' transport is affected by *differences* in the DYNAMIC QUALITY or working condition of steam-ship stock, the calculation being based on the

assumption that the prime cost expense of goods' transport per ton weight of cargo conveyed, will be the sum total of the three following items of outlay and investment, viz. :—

1st. The cost of the fuel consumed per ton weight of cargo conveyed (C.)

2nd. The cost of the Engine Power (H.P.) employed per ton weight of cargo conveyed (E.)

3rd. The cost of the Ship's Tonnage (tons of tonnage) employed per ton weight of cargo conveyed (S.)

The details of prices whereon the cost expenses of the above-mentioned items of expenditure are proposed to be calculated are as follow :—

COAL EXPENSES.

The price of coal will entirely depend on the times and the local circumstances of every particular service; but, for our present illustration, we will assume the average cost of fuel for the entire service at £2 per ton weight of coals consumed.

SHIPPING EXPENSES.

Hull complete, equipped and furnished ready for sea in all respects, at (say) £25 per ton of tonnage, attended with the following annual charges :—

		£	s.	d.
ANNUAL CHARGES PER TON OF TONNAGE	Interest on £25 at 5 per cent. per annum	1	5	0
	Upholding and replacement 10 per cent.	2	10	0
	Wages, including rations, at £3 per 100 tons, per week	1	11	2
	Insurance per annum at 5 per cent ..	1	5	0
	Total annual charges per ton of tonnage	£6	11	2

which is equal to 4½d. per day for 365 days, or 8d. per day sea time, assuming the vessel to be at sea 200 days per annum, exclusive of Harbour-dues, Lights, and Pilotage to be also charged against the cargo.

ENGINE EXPENSES.

Engines complete, ready for sea, at (say) £20 per Indicated h.p. of 33,000lbs. raised 1 foot per minute (*or about £50 per ordinary nominal H.P.*), attended with the following annual charges:—

		£	s.	d.
ANNUAL CHARGES PER INDICATED H.P.	Interest on £20 at 5 per cent.	1	0	0
	Upholding and replacement 10 per cent.	2	0	0
	Wages, including rations, at £5 per 100			
	Indicated h.p. per week	2	12	0
	Consumable stores (coal excepted) at			
	£2 10s. 0d. per 100 Ind. h.p. per week	1	6	0
	Insurance at 5 per cent. per annum	1	0	0
Total annual charges per Indicated h.p.		£7	18	0

which is equivalent to 5d. per day per Indicated h.p. for 365 days, or 9d. per Indicated h.p. per day sea time of 200 days per annum, or 3s. per day per H.P. of the unit 132,000 lbs. raised 1 foot per minute

Applying now the foregoing scale of prices

(viz.—Coal at £2 per ton weight of coal consumed,

Engine power at 3s. per day, per H.P.,

Ship's tonnage at 8d. per day, per ton of tonnage.)

to the quantities shown in the following Table K we obtain the amounts of pecuniary expenditure incurred in the conveyance of each ton of cargo on the passage of 3,250 nautical miles in the different items of Coal expenses (C), Engine expenses (E), and Ship's expenses (S).

TABLE K.—*Showing the variation of the Cost Expenses per ton weight of Cargo occasioned by differences in the QUALITIES of vessels, assuming the average cost of Coal at £2 per ton of coal, the cost of Engine power at 3s. per H.P. per day, and the cost of Ship's tonnage at 8d. per ton of tonnage per day, calculated for vessels of 2,500 tons mean or Mid-passage Displacement, performing a passage of 3,250 nautical miles direct, without re-coaling at any intermediate station,—*

Mid Passage Displacement 2,500 Tons—(TABLE K.)—Passage (direct) 3,250 Nautical Miles.

Coal per Hour	Speed.	Time of Passage.	INDEX NUMBER, 1000.					INDEX NUMBER, 832.					INDEX NUMBER, 664.				
			Power.	Coal.	Cargo.	Deep Dis- placement.	Cost Expenditure per ton of Cargo incurred on Coal (C), Engines (E), Shipping (S).	Power.	Coal.	Cargo.	Deep Dis- placement.	Cost Expenditure per ton of Cargo incurred on Coal (C), Engines (E), Shipping (S).	Power.	Coal.	Cargo.	Deep Dis- placement.	Cost Expenditure per ton of Cargo incurred on Coal (C), Engines (E), Shipping (S).
12lbs. per H.P., or 8lbs. per Ind. h.p.	N.M.	D. H.	H. P.	TONS.	TONS.	TONS.	£ s. d.	H. P.	TONS.	TONS.	TONS.	£ s. d.	H. P.	TONS.	TONS.	TONS.	£ s. d.
	8	16.22	94	205	1304	2602	C 0 6 5 E 0 3 8 S 1 2 6	109	237	1278	2618	C 0 7 7 E 0 4 4 S 1 3 2	142	309	1204	2654	C 0 10 5 E 0 6 0 S 1 4 10
	10	13.13	184	320	1156	2660	C 0 11 2 E 0 6 5 S 1 0 10	213	371	1102	2685	C 0 13 7 E 0 7 10 S 1 2 0	278	484	980	2742	C 0 19 7 E 0 11 6 S 1 5 8
16lbs. per H.P., or 10lbs. per Ind. h.p.	12	11. 7	318	461	952	2780	C 0 19 2 E 0 11 4 S 1 1 7	368	584	865	2767	C 0 14 5 E 0 14 5 S 1 4 1	480	696	672	2848	C 2 1 7 E 1 4 2 S 1 11 10
	8	16.22	94	273	1270	2636	C 0 8 5 E 0 3 9 S 1 4 4	109	316	1233	2658	C 0 10 5 E 0 4 6 S 1 4 4	142	412	1152	2706	C 0 14 5 E 0 6 3 S 1 6 6
	10	13.13	184	427	1103	2713	C 0 15 7 E 0 6 9 S 1 2 2	213	494	1040	2747	C 0 18 10 E 0 8 4 S 1 3 10	278	645	900	2822	C 1 8 10 E 0 12 6 S 1 8 4
20lbs. per H.P., or 12lbs. per Ind. h.p.	12	11. 7	318	615	875	2807	C 1 8 0 E 0 12 4 S 1 4 2	368	712	776	2856	C 0 16 10 E 0 16 0 S 1 7 8	480	929	556	2964	C 3 6 10 E 1 9 3 S 2 0 2
	8	16.22	94	341	1236	2670	C 0 11 2 E 0 3 10 S 1 4 5	109	395	1194	2697	C 0 13 2 E 0 4 8 S 1 5 6	142	515	1101	2757	C 0 18 10 E 0 6 6 S 1 8 3
	10	13.13	184	534	1049	2767	C 0 7 1 E 0 7 1 S 1 3 10	213	618	978	2809	C 0 8 10 E 0 8 10 S 1 5 11	278	807	819	2903	C 1 19 7 E 0 13 10 S 1 12 0
	12	11. 7	318	769	798	2884	C 1 18 5 E 0 13 6 S 1 7 2	368	890	687	2945	C 2 12 0 E 0 18 2 S 1 12 3	480	1161	440	3080	C 5 5 7 E 1 16 11 S 2 12 8

Hence, it appears that if the Index number indicating the dynamic quality of the ship be 862, and the vessel be powered for the speed of 8 knots per hour, and the consumption of fuel be at the rate of 4lbs. per Indicated h.p. per hour, the prime cost expenses of 1 ton weight of cargo on the passage of 3,250 miles, calculated on the before mentioned data, will be £1 19s. 3d., but, if the dynamic quality of the vessel be such as to give the higher index number 1000, and, in combination with such superiority of build and engine-equipment, the boiler department also be such as to reduce the consumption of fuel from 4lbs. to 3lbs. per hour, per Indicated h.p., then the prime cost expenses per ton of cargo will be reduced to £1 12s. 7d., being altogether a reduction on the prime cost expenses per ton of cargo from £1 19s. 3d. to £1 12s. 7d., or about 17 per cent, consequent on such improvement in the dynamic quality of the vessel and in the improved operation of the boilers.

If, on the other hand, the dynamic quality of the vessel be such as to produce the inferior index number 664, and the consumption of fuel be increased from 4lbs. to 5lbs. per hour, per Indicated h.p., the prime cost expenses per ton weight of cargo will, in this case, be increased from £1 19s. 3d. to £2 13s. 7d., being an increased expense of about 36 per cent. consequent on such inferiority in the construction of the vessel and machinery. Now, supposing it be required, in the prosecution of an established trade, to convey 10,000 tons of goods on a passage of 3,250 nautical miles, (being about the distance from Southampton to New York), with vessels of about 2,500 tons, running at the contract speed of 8 knots an hour : if this service be undertaken with steam vessels of superior dynamic qualities and superior mechanical equipment, as indicated by the index number 1000, and the consumption of fuel be

3lbs per hour, per Indicated h.p., or 12lbs. per hour, per H.P. of the unit 132,000lbs., raised 1 foot per minute, then the service will be performed at the prime cost expenditure of £1 12s. 7d. per ton of goods conveyed, amounting to £16,300; but, if the vessels employed be of a medium dynamic quality, as we may suppose to be indicated by the index number 862, and the consumption of fuel be 4lbs. per hour, per Indicated h.p., or 16lbs. per hour, per H.P., then the service will be performed at the prime cost outlay of £1 19s. 3d. per ton of goods conveyed, amounting to £19,625; and if the vessels employed be of inferior dynamic quality, as indicated by the index number 664, and the consumption of fuel be 5lbs. per hour, per Indicated h.p., or 20lbs. per hour, per nominal H.P., then the service will be performed at the prime cost outlay of £2 13s. 7d. per ton of goods conveyed, amounting to £26,800. Thus, in the three cases under consideration the prime cost EXPENSES of performing the service referred to will be £16,300, or £19,625, or £26,800, according to the *differences* in the QUALITIES of the vessels and machinery employed to perform the service. Moreover, if it be required to perform the above mentioned service with vessels of the different dynamic qualities above referred to, but at the increased speed of 10 nautical miles per hour, whereby the time of passage will be reduced from 16 days 22 hours, to 13 days 13 hours, being a saving of 3 days and 9 hours on the passage of 3,250 miles, then, with the vessel whose dynamic QUALITY is represented by the index number 1000, and consumption of fuel at the rate of 3lbs. per hour per Indicated h.p., the prime cost outlay will be at the rate of £1 18 5d. per ton, amounting to £19,200; but, with the vessel of the dynamic QUALITY represented by the index number 862, and consumption of fuel at the rate of 4lbs. per hour per Indicated h.p., the prime cost

outlay will be at the rate of £2 11s. 0d. per ton, amounting to £25,500; and with the vessel of the dynamic quality represented by the index number 664, and the consumption of fuel at the rate of 5lbs. per hour per Indicated h.p., the prime cost outlay will be at the rate of £4 5s. 5d. per ton, amounting to £42,700. Further, at the speed of 12 miles per hour, under the circumstances above referred to the time of passage will be 11 days and 7 hours, being a reduction of 5 days and 15 hours from the time of passage at 8 miles per hour, but the prime cost expenses will be enhanced up to £26,042, £40,250, and £97,583, according to the different QUALITIES of the vessels so employed.

Thus, for the assumed service of conveying 10,000 tons of cargo on a passage of 3,250 nautical miles, with vessels of the different QUALITIES as regards hull, engines, and boilers above referred to, the amounts of prime cost expenditure will be as follow, viz. :—

At the speed of 8 nautical miles per hour, £16,300, or £19,625, or £26,800.

At the speed of 10 nautical miles per hour, £19,200, or £25,500, or £42,700.

At the speed of 12 nautical miles per hour, £26,042, or £40,250, and £97,583.

It is further to be observed that the above amounts are the cost expenses actually incurred, whether the vessel be fully loaded or not, if, therefore, the vessel be inadequately loaded the freight charges per ton of cargo conveyed must be proportionally increased or a positive loss will be sustained; and, moreover, the above amounts do not include Harbour-dues, Lights, and Pilotage, which, being usually rated on the tonnage of the ship without reference to the tons of cargo actually conveyed, will still further enhance the amounts of cost above set forth,—hence the hazard of employing ships of a larger size than the trade will

adequately employ all the year round and ensure being fully loaded, with the least possible detention in port. The *differences* of cost above set forth, and the further considerations above referred to, shew to what an extent the pecuniary prosperity of any steam-ship enterprise is dependent on the judgment of its DIRECTORIAL management, particularly as respects the contract obligations as to SPEED, that may be profitably incurred, in consideration of the remuneration to be received ; the suitable adaptation of the SIZE of the vessel to the commercial demands of the service, and, giving due attention to the dynamic QUALITY of the steam-ship stock in which the capital of the concern may be invested.

We now proceed to the consideration of VESSELS of unprecedented or *hypothetical* MAGNITUDE. It will be observed that the foregoing tabular statements, as originally compiled in 1852, do not embrace the consideration of vessels exceeding 10,000 tons Displacement. Such, however, is the commercial enterprise of the present time, 1854, that a merchant vessel intended to have a Deep-draught Displacement of about 25,000 tons (being about five times the Displacement of the largest ship in the British Navy,) is now actually in progress of construction, this and other projects involving obligations by far surpassing the *ordinary* progress of speculative advancement are now before the public, recognized as enterprises commercially worthy of support. Modern achievements may undoubtedly induce the anticipation of further advancement ; in regard to which, we may assign no limit. The subject matter, which we have undertaken to investigate, is not the limitation of *possibilities* in steam-ship navigation, but, calculating on the basis of already realized data, we attempt to indicate approximately the limitation of engagements that will or will not PAY.

With a view therefore to arrive at some definite, though theoretical, appreciation of the dynamic capabilities of *hypothetical* VESSELS as compared with vessels of ordinary size, and determine the limitation of conditions under which the capabilities of such vessels can be most advantageously developed, the following Table L has been prepared for vessels of 2,500, 5,000, 10,000, and 20,000 tons of mean or Mid-passage Displacement, embracing Deep-draught Displacements up to nearly 30,000 tons, employed on passages of 3,250, 6,500, and 12,500 nautical miles, the DATA on which these calculations are made, as respects weight of hull and engines, consumption of fuel, and Index Number, being the same as before adopted for the Tables, SERIES 1 and 2, viz.,—the weight of the ship's hull, equipment, and stores ready for sea (exclusive of engine department, coal, and cargo) has been assumed to appropriate 40 per cent. of the Mean Displacement, the weight of the engine equipment complete is taken at 1 ton per H.P., or 5 cwt. per Indicated h.p., and the consumption of coals at 4 cwt. per day per H.P. of 132,000lbs. raised 1 foot per minute, or about 4½lbs. per Indicated h.p. per hour. The Index Number denoting the dynamic QUALITY of the ship being assumed at 862, and the details of COST EXPENSES being the same as set forth in page 77.

NOTE.—The statement submitted by the author to the Institution of Civil Engineers, London, in the discussion on the "Capabilities of large Steam-ships," is introduced in the APPENDIX, and may be referred to, for, irrespective of collateral discussion, not immediately connected with the matter now before us, it explains the grounds of the author's proceedings and brings under review various considerations that would not otherwise be appropriately introduced into the text of this work.

By the foregoing Table (L) we observe the decided SUPERIOR CAPABILITY as respects *economy* of goods' transport or *freight* which is the inherent property of large ships as compared with smaller vessels, if competing against each other under *similar* conditions as to *speed and distance* without re-coaling,—for example, on a passage of 3,250 nautical miles, at the speed of 12 knots per hour, the cost expenses per ton of cargo by the 4 different sizes of vessels referred to in the Table will be at the respective rates of £4 14s. 5d.; £3 5s. 1d.; £2 9s. 4d.; and £1 19s. 1d. Also on a passage of 6,500 nautical miles without re-coaling, at the speed of 12 knots per hour; the cost expenses will be at the respective rates of £23 8s. 8d.; £10 16s. 1d.; £6 18s. 7d.; and £4 19s. 6d., and on a passage of 12,500 nautical miles without re-coaling the vessels of 2,500 and 5,000 tons Mean or Mid-passage Displacement, will be incapable of making the passage at the speed of 12 nautical miles per hour, and the vessels of 10,000 and 20,000 tons will respectively incur the cost of £40 17s. 3d. and £17 16s. 7d. per ton of cargo conveyed. In these comparisons it has been presumed that the smaller vessels do not re-coal on the voyage, and that the larger vessels will not be detained in Port for cargo, or otherwise, longer than the smaller vessels; the calculations being made for 200 days sea time per annum and on the data as to details of cost expenses enunciated at page 77.

Further, the *superior capabilities* of large ships as compared with smaller vessels in respect of SAVING TIME when running at nearly *equal rates of cost expenses* per ton weight of cargo conveyed will be equally apparent, for, by inspecting Table L, it appears that on a passage of 6,500 nautical miles without re-coaling, the 4 different sizes of vessel will incur about the same rate of cost expenses per ton of cargo if the vessels be respectively

fitted for steaming at the speeds of 9 knots per hour, $10\frac{1}{4}$ knots, $11\frac{1}{2}$ knots and 13 knots per hour; the corresponding time being 30d. 2h., 26d. 1h., 23d. 13h., and 20d. 20h.; also it appears that on a passage of 12,500 nautical miles without re-coaling, the rates of speed by vessels of the respective sizes referred to, steaming at equal rates of cost per ton of cargo (say about £25) will be about 9 knots, $10\frac{1}{4}$ knots, $11\frac{1}{2}$ knots, and $12\frac{3}{4}$ knots per hour, and the time will be about 57d. 21h., 50d. 20h., 45d. 7h., and 40d. 20h.. It may be observed that higher speed and consequently less time of passage are practicable, but it is supposed to be a commercially useless speculation to contemplate the incurring of a higher scale of freight charge than £25 per ton for the conveyance of cargo on a passage of 12,500 nautical miles.

Thus the *superior capability* of large ships as compared with smaller vessels in regard either to *economy* of freight EXPENSES per ton of cargo when steaming at equal speed, or to *economy* of TIME at the same scale of freight charges, are obvious. But still, inasmuch as small vessels have greater facilities of access to port, and consequently more frequent opportunities for re-coaling than are available to larger vessels it remains to be considered in what degree and to what an extent the superior dynamic capabilities of large ships will enable such ships to defy the competition of smaller vessels in the case of the service in which the larger ship may be employed, not admitting of her re-coaling at the intermediate Ports which may be accessible to her rival, the smaller vessel, at the same time duly bringing to account against the smaller vessel, the greater distance measured from port to port which the smaller vessel may have to travel as compared with the more *direct* passage of the larger ship. To investigate this case the following Table (M) has been prepared :—

TABLE M.

Shewing the cost expenses per ton weight of Cargo on a passage of 12,500 nautical miles by vessels of 2,500 tons mean Displacement, making the whole passage in 8 stages of 1,750 miles; vessels of 5,000 tons mean Displacement making the passage in 4 stages of 3,250 miles; vessels of 10,000 tons mean Displacement making the passage in 2 stages of 6,500 miles; and vessels of 20,000 tons mean Displacement making the passage of 12,500 miles direct. Index number 862.

Knots an hour	M. M.	Mean Displacement 2,500 tons weight. Voyage performed in 8 stages of 1,750 nautical miles, re-coaling at 7 inter- mediate stations.				Mean Displacement 5,000 tons weight. Voyage performed in 4 stages of 3,250 nautical miles, re-coaling at 8 inter- mediate stations.				Mean Displacement 10,000 tons weight. Voyage performed in 2 stages of 6,500 nautical miles, re-coaling at 1 inter- mediate station.				Mean Displacement 20,000 tons weight. Voyage of 12,500 nautical miles, per- formed without re-coaling at any inter- mediate station.			
		SEA TIME. D. H.	QUANTITIES.	TONS OF CARGO & EXPENSES PER TON. £ s. d.	£ s. d.	SEA TIME. D. H.	QUANTITIES.	TONS OF CARGO & EXPENSES PER TON. £ s. d.	£ s. d.	SEA TIME. D. H.	QUANTITIES.	TONS OF CARGO & EXPENSES PER TON. £ s. d.	£ s. d.	SEA TIME. D. H.	QUANTITIES.	TONS OF CARGO & EXPENSES PER TON. £ s. d.	£ s. d.
8		72.22	{ C 1590 Tons E 109 H.P. 0 18 5 S 2099 Tons 4 18 0 }	2 9 8 1292 at 8 5 8	7 4 6	67.16	{ C 2828 Tons E 172 H.P. 0 18 9 S 5291 Tons 4 14 1 }	1 16 8 2587 at 7 4 6	7 4 6	67.16	{ C 8738 Tons E 276 H.P. 0 11 8 S 10984 Tons 5 8 0 }	1 11 8 4790 at 7 5 11	7 5 11	65.2	{ C 5677 Tons E 486 H.P. 0 9 9 S 22888 Tons 5 13 7 }	1 6 0 8725 at 7 9 4	7 9 4
9		64.20	{ C 2010 Tons 3 5 11 E 155 H.P. 1 4 9 S 2626 Tons 4 18 1 }	1219 at 9 3 9	7 13 3	60.4	{ C 2948 Tons 2 9 5 E 245 H.P. 0 18 7 S 5968 Tons 4 10 3 }	2886 at 7 13 3	7 13 3	60.4	{ C 4673 Tons 2 2 1 E 888 H.P. 0 15 9 S 11168 Tons 5 0 10 }	4444 at 7 13 8	7 13 8	57.21	{ C 7176 Tons 1 16 11 E 620 H.P. 0 18 10 S 28688 Tons 5 16 9 }	1 16 11 7792 at 8 7 6	8 7 6
10		58.8	{ C 2485 Tons 4 7 10 E 218 H.P. 1 12 11 S 2655 Tons 4 11 8 }	1132 at 10 12 0	8 16 5	54.4	{ C 3528 Tons 3 8 6 E 386 H.P. 1 4 7 S 5441 Tons 4 8 4 }	2228 at 8 16 5	8 16 5	54.4	{ C 5908 Tons 2 17 10 E 586 H.P. 1 1 8 S 11451 Tons 5 8 1 }	4013 at 9 2 7	9 2 7	52.2	{ C 8875 Tons 2 13 11 E 852 H.P. 0 19 10 S 24487 Tons 6 6 5 }	2 13 11 6711 at 9 19 2	9 19 2
11		53.1	{ C 8012 Tons 5 17 2 E 284 H.P. 2 8 11 S 2688 Tons 4 12 6 }	1028 at 12 13 7	10 12 3	49.4	{ C 4412 Tons 4 8 8 E 448 H.P. 1 18 0 S 5551 Tons 4 11 0 }	2000 at 10 12 3	10 12 3	49.4	{ C 7012 Tons 3 19 4 E 712 H.P. 1 9 8 S 11753 Tons 5 9 0 }	3535 at 10 13 0	10 13 0	47.8	{ C 10757 Tons 3 18 4 E 1136 H.P. 1 9 5 S 25878 Tons 7 6 0 }	3 18 4 12 13 9	12 13 9
12		48.15	{ C 8551 Tons 7 16 1 E 368 H.P. 2 18 6 S 2722 Tons 4 16 8 }	910 at 15 10 10	13 0 3	45.4	{ C 5244 Tons 5 11 0 E 581 H.P. 2 4 8 S 5655 Tons 4 16 7 }	1763 at 13 0 3	13 0 3	45.4	{ C 8378 Tons 5 12 6 E 928 H.P. 2 2 8 S 12094 Tons 6 2 8 }	2978 at 13 17 0	13 17 0	48.10	{ C 12778 Tons 6 8 6 E 1472 H.P. 2 6 4 S 26889 Tons 9 6 9 }	6 8 6 17 16 7	17 16 7
13		44.21	{ C 4200 Tons 10 18 2 E 468 H.P. 4 1 10 S 2762 Tons 5 7 4 }	770 at 20 7 4	16 14 9	41.16	{ C 6160 Tons 8 5 8 E 789 H.P. 3 2 0 S 5770 Tons 5 7 6 }	1491 at 16 14 9	16 14 9	41.16	{ C 9804 Tons 8 6 7 E 1180 H.P. 3 2 5 S 12488 Tons 7 6 6 }	2863 at 18 15 6	18 15 6	40.2	{ C 15002 Tons 11 8 5 E 1872 H.P. 4 5 8 S 27501 Tons 13 19 9 }	11 8 5 2627 at 20 13 10	20 13 10
14		41.16	{ C 4875 Tons 15 19 8 E 585 H.P. 5 19 11 S 2805 Tons 6 7 9 }	610 at 23 7 4	23 0 1	38.16	{ C 7144 Tons 12 1 4 E 928 H.P. 4 10 5 S 5898 Tons 6 8 4 }	1184 at 23 0 1	23 0 1	38.16	{ C 11894 Tons 13 11 3 E 1472 H.P. 6 1 8 S 12848 Tons 9 17 2 }	1680 at 23 10 1	23 10 1	37.5	{ C 17420 Tons 26 18 4 E 2840 H.P. 13 15 0 S 28710 Tons 37 9 8 }	26 18 4 950 at 27 13 0	27 13 0
15		38.21	{ C 5598 Tons 26 0 9 E 720 H.P. 9 15 5 S 2840 Tons 8 11 11 }	480 at 44 8 1	35 9 9	36.4	{ C 8196 Tons 19 0 8 E 1185 H.P. 7 6 7 S 6024 Tons 8 12 11 }	840 at 35 9 9	35 9 9	36.4	{ C 18086 Tons 39 11 5 E 1812 H.P. 10 14 8 S 13271 Tons 17 9 4 }	916 at 36 15 5	36 15 5	-	-	-	-
		Add 7 days for re-coaling.				Add 6 days for re-coaling.				Add 4 days for re-coaling.				No detention at any intermediate port.			

It is to be observed that the larger vessel performs its passage of 12,500 miles *direct*, but the time of passage of the smaller vessels will be increased by their greater distance to be run in going out of their direct course for coaling stations, as well as by their detention at the stations for re-coaling; for which purpose we assume that the vessel of 2,500 tons, Mean Displacement, will be detained 1 day at each of the 7 intermediate stations, being a detention of 7 days; the vessel of 5,000 tons, 2 days at each of the 3 intermediate stations, being a detention of 6 days; and the vessel of 10,000 tons, 4 days at its 1 intermediate coaling station, being a detention of 4 days. Now, on inspecting the Table (M) subject to the above correction as to detention for re-coaling, it appears that a ship of the hitherto *unprecedented* magnitude of 26,389 tons Deep-draught Displacement, steaming at 12 knots per hour will convey goods on a 12,500 mile direct passage (say from England to Calcutta) at the freight cost of £17 16s. 7d. per ton of cargo, and the time of passage will be 43 days 10 hours; but a vessel about half the size, viz., 12,094 tons, re-coaling at 1 intermediate station, will perform the same service in 49 days 4 hours, at the freight cost of £13 17s. 0d. per ton of cargo, being 5 days 18 hours greater time, but £3 19s. 7d. per ton less cost. A vessel of about one-fourth the size, viz., 5,655 tons, re-coaling at three intermediate stations will perform the same service in 51 days 4 hours, at the freight cost of £13 0s. 3d. per ton of cargo, being 7 days 18 hours greater time, but £4 16s. 4d. per ton less cost. And a vessel of about one-eighth of the size, viz., 2,722 tons, re-coaling at 7 intermediate stations will perform the same service in 55 days 15 hours, at the freight cost of £15 10s. 10d. per ton of cargo, being 12 days 5 hours greater time, but £2 5s. 9d. per ton less cost. It will be

entirely a commercial consideration, in connection with any particular service, to determine at what rate of *extra cost*, *economy* of TIME may be advantageously purchased.

These calculations shewing the mutual relation of time saved and extra expense incurred in the above cases of service, greatly modify the advantages to be derived from the admitted superior capabilities of large ships, and it is further to be observed that they have reference only to the locomotive or dynamic capabilities of the respective ships, in a mechanical point of view, without regard to the mercantile and nautical considerations in respect to numerous details of commercial management, which must materially influence the decision of steam-ship Direction as to the SIZE of vessel by which any proposed service may be most beneficially prosecuted.

The foregoing £ s d results being based on arbitrary data, are given as an exemplification of a SYSTEM of mercantile cost-price calculation, with reference to which, the author would repeat the expression of sentiments with which he prefaced the foregoing pages, viz.,—that the task which he has attempted to discharge has been to propound some SYSTEM for bringing under review, however approximately, the relative dynamic QUALITIES and CAPABILITIES of steam-ships, as measured by the mutual relation of DISPLACEMENT, POWER, and SPEED, with reference to the cost expenses of freight per ton of cargo conveyed—a system of investigation which may be regarded as the ARITHMETIC of steam-ship *adaptation* to the *requirements* of MERCANTILE SERVICE ; an arithmetic hitherto neglected, but of which the importance can scarcely be over estimated in these days of commercial rivalry, and of national intercourse chiefly dependent on, and prosecuted by, the agency of STEAM.

STEAM-SHIP CONSUMPTION OF COALS.

The consumption of COALS being a consideration of primary importance as affecting the prosecution of any steam-ship project, it may be useful to expose the relation which subsists between steam-ship DISPLACEMENT, SPEED, and COALS, accordingly, the following Table has been prepared to shew the daily consumption of Coal that may be expected to be required for the propulsion of a ship of given Displacement, at a given rate of Speed, the Table being based on the assumption that, the locomotive or dynamic quality of the ship, if intended for the conveyance of goods and passengers, will be equal to that of H.M. steam-ship *Rattler* (page 17 and 18) and that the average consumption of Coals on continued service, will be at the rate of $4\frac{1}{2}$ lbs. per hour, per Indicated h.p. of 33,000 lbs., raised one foot per minute. On these data, the tabulated results are believed to be a favourable estimate of present Marine Engine Practice with Engines and Boilers in ordinary condition, and working on the principle of condensation and restricted steam pressure, as usually adopted on board ship. A further purpose for which this Table has been constructed is, that it may enable merchants to judge for themselves of the Locomotive efficiency of any steam-ship, as respects its type of form and Engine-adaptation thereto, by means of the ascertained quantity of Coals that may be actually consumed per day, in the performance of any given service, as compared with the tabulated consumption under

similar circumstances of Displacement and Speed. For example:—by reference to the Table, it appears that a ship of 3,500 tons Displacement, steaming at the speed of 12 knots per hour, may be expected to consume 89 tons of Coal per day; if however, it be found that the actual consumption be within that limit, it may be inferred that the ship and its machinery is, as respects Locomotive effect, of a superior order; but if the consumption exceed that rate, amounting to say, 100 tons per day, it will then be known either that the vessel is of comparatively inferior type of form, or that the Engines and Boilers are of inferior construction, or in defective condition, or badly managed, and the existence of constructive inferiority, or of defective condition, or of bad management being thus ascertained, a material step will have been gained towards detecting and correcting the evil.* By thus bringing to account the actual consumption of Coals with reference to some standard measure of duty—such for instance as that set forth in the Table—we shall obtain a mercantile test of the constructive quality and condition of steam-ship stock. The intrinsic merit of each steam-ship, as respects its type of Form and Engine-efficiency, will thus be brought within the scope of counting-house scrutiny, based on counting-house record of Displacement, Speed, and Coals; and the delusion which usually attends all mercantile reference to “Nominal Horse-power”—a term which merchants do not generally understand, and to which neither legislative enactment nor engineering practice has attached any definite meaning whatever, as a standard measure of power (Appendix 2, letter 2)—will in a great measure be obviated.

* On Marine Boilers.—See Atherton's Essay on “Marine Engine Construction and Classification.” Published by WEALE. Page 34.

COAL TABLE No. 1.

Shewing the mutual relation of DISPLACEMENT, SPEED, and Daily consumption of COAL, for vessels adapted for the transport of Goods and Passengers of which the co-efficient of locomotive performance is equal to that of RATTLER, assuming the consumption to be at the rate of $4\frac{1}{2}$ lbs. per Indicated h.p. per hour, the quantity consumed being expressed in tons per day of 24 hours.

SHIP'S DISPLACE- MENT.	SPEED PER HOUR.—NAUTICAL MILES.																			
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20					
TONS.	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS					
100	1.04	1.65	2.47	3.51	4.82	6.41	8.32	10.6	13.2	16.3	19.7	23.7	28.1	33.0	38.5					
125	1.20	1.92	2.86	4.07	5.59	7.44	9.66	12.3	15.3	18.9	22.9	27.5	32.6	38.3	44.7					
150	1.36	2.16	3.23	4.60	6.31	8.40	10.9	13.9	17.3	21.3	25.9	31.0	36.8	43.3	50.5					
175	1.51	2.40	3.58	5.10	7.00	9.31	12.1	15.4	19.2	23.6	28.7	34.4	40.8	48.0	56.0					
200	1.65	2.62	3.91	5.57	7.65	10.2	13.2	16.8	21.0	25.8	31.3	37.6	44.6	52.4	61.2					
250	1.92	3.04	4.54	6.47	8.87	11.8	15.3	19.5	24.3	29.9	36.3	43.6	51.7	60.9	71.0					
300	2.25	3.44	5.13	7.30	10.0	13.3	17.3	22.0	27.5	33.8	41.0	49.2	58.4	68.7	80.1					
350	2.40	3.81	5.68	8.09	11.1	14.8	19.2	24.4	30.5	37.5	45.5	54.5	64.7	76.2	88.8					
400	2.62	4.16	6.21	8.85	12.1	16.2	21.0	26.7	33.3	41.0	49.7	59.6	70.8	83.3	97.1					
450	2.84	4.50	6.72	9.57	13.1	17.5	22.7	28.8	36.0	44.3	53.8	64.5	76.6	90.1	105					
500	3.04	4.83	7.21	10.3	14.1	18.7	24.3	30.9	38.6	47.5	57.7	69.2	82.1	96.6	113					
600	3.43	5.46	8.14	11.6	15.9	21.2	27.5	34.9	43.6	53.7	65.1	78.1	92.8	109	127					
700	3.81	6.05	9.02	12.8	17.6	23.5	30.4	38.7	48.4	59.5	72.2	86.6	103	121	141					
800	4.16	6.61	9.87	14.0	19.3	25.6	33.3	42.3	52.9	65.0	78.9	94.6	112	132	154					
900	4.50	7.15	10.7	15.2	20.8	27.7	36.0	45.8	57.2	70.4	85.4	102	122	143	167					
1000	4.83	7.67	11.4	16.3	22.4	29.8	38.6	49.1	61.3	75.5	91.6	110	130	153	179					
1250	5.60	8.90	13.3	18.9	26.0	34.5	44.8	57.0	71.2	87.6	106	127	151	178	208					
1500	6.33	10.0	15.0	21.4	29.3	39.0	50.6	64.4	80.4	98.9	120	144	171	201	234					
1750	7.01	11.1	16.6	23.7	32.5	43.2	56.1	71.3	89.1	110	133	159	189	223	260					
2000	7.66	12.2	18.2	25.9	35.5	47.3	61.3	77.9	97.4	120	145	174	207	243	284					
2500	8.89	14.1	21.1	30.0	41.2	54.8	71.2	90.5	113	139	169	202	240	283	329					
3000	10.0	16.0	23.8	33.9	46.5	61.9	80.4	102	128	157	191	228	271	319	372					
3500	11.1	17.7	26.4	37.6	51.5	68.6	89.0	113	141	174	211	253	301	354	412					
4000	12.2	19.3	28.8	41.1	56.3	75.0	97.3	124	155	190	231	277	329	386	451					
5000	14.1	22.4	33.5	47.7	65.4	87.0	113	144	179	221	268	321	381	448	523					
6000	15.9	25.3	37.8	53.8	73.8	98.3	128	162	203	249	302	353	431	506	591					
7000	17.7	28.1	41.9	59.6	81.8	109	141	180	224	276	335	402	477	561	654					
8000	19.3	30.7	45.8	65.2	89.4	119	155	196	245	302	366	439	522	613	715					
9000	20.9	33.2	49.5	70.5	96.7	129	167	213	265	327	393	475	564	663	774					
10000	22.4	35.6	53.1	75.6	104	138	179	228	285	350	425	510	605	712	830					
12500	26.0	41.3	61.7	87.8	120	160	208	265	330	406	493	592	702	826	963					
15000	29.4	46.6	69.6	99.1	136	181	235	299	373	459	557	668	793	933	1088					
20000	35.6	56.5	84.4	120	165	219	285	362	452	556	675	809	961	1130	1318					
25000	41.3	65.6	97.9	139	191	254	330	420	525	645	783	939	1115	1311	1529					
30000	46.6	74.0	111	157	216	287	373	474	592	728	884	1060	1253	1480	1727					

The foregoing Table may be regarded as applicable to sea-going steam-ships, as usually built and fitted for the speedy conveyance of Mails, Passengers, and Goods; it may, however, be a subject of consideration, whether in many cases of service in which *economy* of transport becomes indispensable to the continued prosecution of the service itself, it may not be advisable to convey Mails, Passengers, and Goods by vessels built expressly for the development of sailing properties, but using steam as occasional auxiliary power to ensure *punctuality*, rather than performing such service by vessels built expressly for being propelled by steam-power only. It may also be desirable that proprietors of sailing vessels ascertain how far their existing stock of ships could be advantageously made available as steamers fitted with auxiliary power for combining economy, punctuality, and moderate speed, the solution of which enquiry will be mainly dependant on the daily consumption of Coals that will be involved under any given conditions of Displacement and Speed. Moreover, it may be useful to ascertain promptly by inspection, the variable consumption of Coals necessary for the propulsion of ships-of-war, constructed as usual on a type of *immersed* form adapted for the development of sailing properties, according to the different degrees of speed at which it may be found expedient to propel such vessels by steam.

To meet these various cases, the following Table No. 2, has been calculated on the type of form adapted for sailing properties as exemplified by H.M. steam-frigate *Arrogant*, of which the principal elements are shewn at page 11. The results of this Table, No. 2, are about 30 per cent. in *excess* of the quantities shewn by Table No. 1, under similar circumstances of Displacement and Speed, attributable to the *differences* in construction only, the consumption of Coals per Ind. h.p. per hour being in both cases the same.

COAL TABLE No. 2.

Shewing the mutual relation of DISPLACEMENT, SPEED, and Daily consumption of COAL for SAILING-SHIPS using auxiliary steam power, of which the Co-efficient of Dynamic performance is equal to that of H.M. steam-frigate ARROGANT, assuming the consumption of Coals to be at the rate of $4\frac{1}{2}$ lbs. per Ind. h.p. per hour, the quantity consumed being expressed in tons per day of 24 hours.

SHIP'S DISPLACE- MENT.	SPEED PER HOUR.—NAUTICAL MILES.																		
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20				
TONS.	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS
100	1.35	2.14	3.21	4.56	6.26	8.33	10.8	13.7	17.1	21.2	25.6	30.8	36.5	42.9	50.0				
125	1.56	2.49	3.71	5.29	7.26	9.67	12.5	16.0	19.9	24.5	29.7	35.7	42.3	49.7	58.1				
150	1.76	2.80	4.20	5.98	8.20	10.9	14.1	18.0	22.5	27.7	33.6	40.3	47.8	56.3	65.6				
175	1.96	3.12	4.65	6.63	9.10	12.1	15.7	20.0	24.9	30.6	37.3	44.7	53.0	62.4	72.8				
200	2.14	3.40	5.08	7.24	9.94	13.2	17.1	21.8	27.3	33.5	40.7	48.8	57.9	68.1	79.5				
250	2.49	3.95	5.90	8.41	11.5	15.3	19.9	25.3	31.6	38.8	47.2	56.6	67.2	79.1	92.3				
300	2.92	4.47	5.67	9.49	13.0	17.3	22.5	28.6	35.7	43.9	53.3	63.9	75.9	89.3	104				
350	3.12	4.95	7.38	10.5	14.4	19.2	24.9	31.7	39.6	48.7	59.1	70.8	84.1	99.0	115				
400	3.40	5.41	8.07	11.5	15.7	21.0	27.3	34.7	43.3	53.3	64.6	77.4	92.0	108	126				
450	3.69	5.85	8.73	12.4	17.0	22.7	29.5	37.4	46.8	57.5	69.9	83.8	99.5	117	136				
500	3.95	6.28	9.37	13.4	18.3	24.3	31.6	40.1	50.2	61.7	75.0	89.9	106	125	147				
600	4.46	7.10	10.6	15.1	20.6	27.5	35.7	45.3	56.6	69.8	84.6	101	120	141	165				
700	4.95	7.86	11.7	16.6	22.8	30.5	39.5	50.3	62.9	77.3	93.8	112	134	157	183				
800	5.41	8.59	12.8	18.2	25.1	33.3	43.3	55.0	68.7	84.5	102	123	145	171	200				
900	5.85	9.29	13.9	19.7	27.0	36.0	46.8	59.5	74.3	91.5	111	132	158	186	217				
1000	6.28	9.97	14.8	21.2	29.1	38.7	50.1	63.8	79.7	98.1	119	143	169	199	232				
1250	7.28	11.5	17.3	24.5	33.8	44.8	58.2	74.1	92.5	114	137	165	196	231	270				
1500	8.23	13.0	19.5	27.8	38.1	50.7	65.7	83.7	104	128	156	187	222	261	304				
1750	9.11	14.4	21.5	30.8	42.2	56.1	72.9	92.7	115	143	173	206	245	290	338				
2000	9.95	15.8	23.6	33.6	46.1	61.5	79.7	101	126	159	188	226	269	316	369				
2500	11.5	18.3	27.4	39.0	53.5	71.2	92.5	117	147	180	219	262	312	368	427				
3000	13.0	20.8	30.9	44.0	60.4	80.4	104	132	166	204	248	296	352	414	483				
3500	14.4	23.0	34.3	48.8	66.9	89.1	115	147	183	226	274	329	391	460	535				
4000	15.8	25.1	37.4	53.4	73.2	97.5	126	161	201	247	300	360	427	501	586				
5000	18.3	29.1	43.5	62.0	85.0	113	147	187	232	287	348	417	495	582	679				
6000	20.6	32.9	49.1	69.9	95.9	127	166	210	264	323	392	472	560	657	768				
7000	23.0	36.5	54.4	77.4	106	141	183	234	291	358	435	522	620	729	850				
8000	25.1	39.9	59.5	84.7	116	154	201	254	318	392	475	570	678	796	929				
9000	27.1	43.1	64.3	91.6	125	167	217	276	344	425	514	617	733	861	1006				
10000	29.1	46.2	69.0	98.2	135	179	232	296	370	455	552	663	786	925	1079				
12500	33.8	53.6	80.2	114	156	208	270	344	429	527	640	769	912	1073	1251				
15000	38.2	60.5	90.4	128	176	235	305	388	484	596	724	868	1030	1212	1414				
20000	46.2	73.4	109	156	214	284	370	470	587	722	877	1051	1249	1469	1713				
25000	53.7	85.2	127	180	248	330	429	546	682	838	1018	1220	1449	1704	1987				
30000	60.5	96.2	144	204	280	373	485	616	769	946	1149	1378	1635	1924	2245				

PROSPECTIVE IMPROVEMENTS.

Further, with reference to Table No. 1, the superiority of *Rattler* (constructed in 1841) over vessels of more recent construction as respects the type of form best adapted to the development of a high degree of locomotive effect, is admitted to be a most unexpected result and of statistical enquiry ; and although the author may not in his own experience have met with any superior example of steam-ship performance, when measured by the test formula $\frac{V^3 D^{\frac{1}{2}}}{\text{IND. h.p.}} = C$, still it may be presumed that steam-ship constructive science has not been altogether at bay, or at least it is to be expected that improvement will result from attention being directed to so important a subject, and a SYSTEM of *Test* established for subjecting the *relative* merit of steam-ships to mercantile scrutiny. Hence, as the Co-efficient or Index Number of locomotive performance of *Rattler* deduced by the formula $\frac{V^3 D^{\frac{1}{2}}}{\text{IND. h.p.}} = C$, is 215 (see Appendix No. 4) we may surely anticipate such improvement in the type of form of steam-ships as will raise the Co-efficient from 215 up to 250.

In the Engine department also, it has been for years past well known that in Mining operations the consumption of Coals, with reference to power, has been reduced to nearly 2lbs. of Coal per Ind. h.p., per hour, whilst marine engines have ordinarily consumed more than the double of that quantity. Hence, seeing the premium that exists for a reduced consumption of Coal on board ship, it may be reasonably anticipated that a reduction from the present ordinary consumption of 4½lbs. down to 3lbs. per hour per Ind. h.p. will be gradually effected.*

On these assumptions, combining a prospectively improved type of ship with improved construction and management, the following Table, No. 3, has been calculated, shewing a *reduced* consumption of about 42 per cent. as compared with Table No. 1, under similar circumstances of Displacement and Speed.

* Marine Engine Construction and Classification. Pages 73, 74.

COAL TABLE No. 3.

Shewing the mutual relation of DISPLACEMENT, SPEED, and Daily consumption of COAL, for prospectively improved Vessels of which the assumed Co-efficient of locomotive performance (deduced from formula $\frac{v^3 D^{\frac{3}{2}}}{\text{IND. h.p.}} = C$) shall be equal to 250; assuming also the consumption of Coals to be at the rate of 3lbs per Ind. h.p. per hour, the quantity consumed being expressed in tons per day of 24 hours.

SHIP'S DISPLACE- MENT.	SPEED PER HOUR.—NAUTICAL MILES.																			
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20					
TONS.	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS	TONS					
100	.598	.949	1.42	2.02	2.77	3.69	4.78	6.09	7.59	9.37	11.3	13.6	16.2	19.0	22.1					
125	.696	1.10	1.64	2.34	3.21	4.28	5.55	7.07	8.80	10.9	13.2	15.8	18.7	22.0	25.7					
150	.782	1.24	1.86	2.64	3.63	4.83	6.27	7.99	9.95	12.2	14.9	17.8	21.2	24.9	29.0					
175	.868	1.38	2.06	2.93	4.02	5.35	6.96	8.85	11.0	13.6	16.5	19.8	23.5	27.6	32.2					
200	.949	1.51	2.25	3.20	4.40	5.86	7.59	9.66	12.1	14.8	18.0	21.6	25.6	30.1	35.2					
250	1.10	1.75	2.61	3.72	5.10	6.78	8.80	11.2	14.0	17.2	20.9	25.1	29.7	35.0	40.8					
300	1.29	1.98	2.95	4.20	5.75	7.65	9.95	12.6	15.8	19.4	23.6	28.3	33.6	39.5	46.1					
350	1.38	2.19	3.27	4.65	6.38	8.51	11.0	14.0	17.5	21.6	26.2	31.3	37.2	43.8	51.1					
400	1.51	2.39	3.57	5.09	6.96	9.31	12.1	15.3	19.1	23.6	28.6	34.3	40.7	47.9	55.8					
450	1.63	2.59	3.86	5.50	7.53	10.1	13.0	16.6	20.7	25.5	30.9	37.1	44.0	51.8	60.4					
500	1.75	2.78	4.15	5.92	8.11	10.8	14.0	17.8	22.2	27.3	33.2	39.8	47.2	55.5	65.0					
600	1.97	3.14	4.68	6.67	9.14	12.2	15.8	20.1	25.1	30.9	37.4	44.9	53.4	62.7	73.0					
700	2.19	3.48	5.19	7.36	10.1	13.5	17.5	22.2	27.8	34.2	41.5	49.8	59.2	69.6	81.1					
800	2.39	3.80	5.67	8.05	11.1	14.7	19.1	24.3	30.4	37.4	45.4	54.4	64.4	75.9	88.5					
900	2.59	4.11	6.15	8.74	12.0	15.9	20.7	26.3	32.9	40.5	49.1	58.6	70.1	82.2	96.0					
1000	2.78	4.41	6.56	9.36	12.9	17.1	22.2	28.3	35.2	43.6	52.8	63.2	74.8	88.0	103					
1250	3.22	5.12	7.65	10.9	14.9	19.8	25.8	32.8	40.9	50.4	60.9	73.0	86.8	102	120					
1500	3.64	5.75	8.62	12.3	16.8	22.4	29.1	37.0	46.2	56.9	69.0	82.8	98.3	116	135					
1750	4.03	6.38	9.54	13.6	18.7	24.8	32.3	41.0	51.2	63.2	76.5	91.4	109	128	149					
2000	4.40	7.00	10.4	14.9	20.4	27.1	35.2	44.8	56.0	68.8	83.6	100	119	140	163					
2500	5.11	8.11	12.1	17.2	23.7	31.5	40.9	52.0	65.0	79.9	97.2	116	138	163	189					
3000	5.75	9.20	13.7	19.5	26.7	35.6	46.2	58.6	73.6	90.3	110	131	156	183	214					
3500	6.38	10.2	15.2	21.6	29.6	39.4	51.2	65.0	81.1	100	121	145	173	204	237					
4000	7.00	11.1	16.6	23.7	32.4	43.2	56.0	71.2	88.8	109	133	159	189	222	260					
5000	8.11	12.9	19.3	27.4	37.6	50.0	65.0	82.8	103	127	154	185	219	258	301					
6000	9.14	14.5	21.7	30.9	42.4	56.5	73.6	93.1	117	143	174	209	248	291	340					
7000	10.2	16.2	24.1	34.3	47.0	62.7	81.1	103	129	159	193	231	274	323	376					
8000	11.1	17.6	26.2	37.5	51.5	68.5	88.8	113	141	174	211	253	299	352	412					
9000	12.0	19.1	28.5	40.5	55.6	74.2	96.0	122	152	188	228	273	324	381	445					
10000	12.9	20.5	30.6	43.5	59.8	79.3	103	131	164	201	244	292	347	409	478					
12500	14.9	23.7	35.5	50.5	69.0	92.0	120	152	190	233	283	340	404	475	554					
15000	16.9	26.8	40.0	57.0	78.2	104	135	172	214	264	320	384	456	536	626					
20000	20.4	32.4	48.5	69.0	94.8	126	164	208	260	320	389	465	552	651	757					
25000	23.7	37.7	56.3	79.9	110	146	190	241	302	371	450	540	641	754	879					
30000	26.8	42.5	63.8	90.3	124	165	214	273	340	419	508	609	723	851	993					

APPENDIX.

THE annexed DIAGRAM exemplifies a system whereby the mutual relation of Displacement, Power, and Speed may be shown generally for vessels of any size. The base line of the Diagram is divided into a scale of equal parts, representing the mean displacements; and from certain determined points thereon, as at the points of the scale marked 500, 1000, 2000, 3000, &c., vertical lines are drawn of a length proportional to the variations of power (H.P.) (*calculated* as in Tables A, B, C, D,) required to propel vessels of these respective displacements at any specified rate of speed; and a curve line is then drawn through the *extremities* of the said vertical lines. If, now, from the point on the base line which represents any particular amount of mean displacement, a vertical line be drawn up to the curve, the length of the said vertical line, measured on the scale of H.P., will represent the power required to propel the vessel at the speed for which the curve may have been drawn. For example, a ship of 750 tons' mean displacement, of which the index number is 862, requires about 50 H.P. for eight nautical miles per hour; about 100 H.P. for ten miles; 160 H.P. for twelve miles; 260 H.P. for fourteen miles; 400 H.P. for sixteen miles; 550 H.P. for eighteen miles; and 760 H.P. for twenty nautical miles per hour,

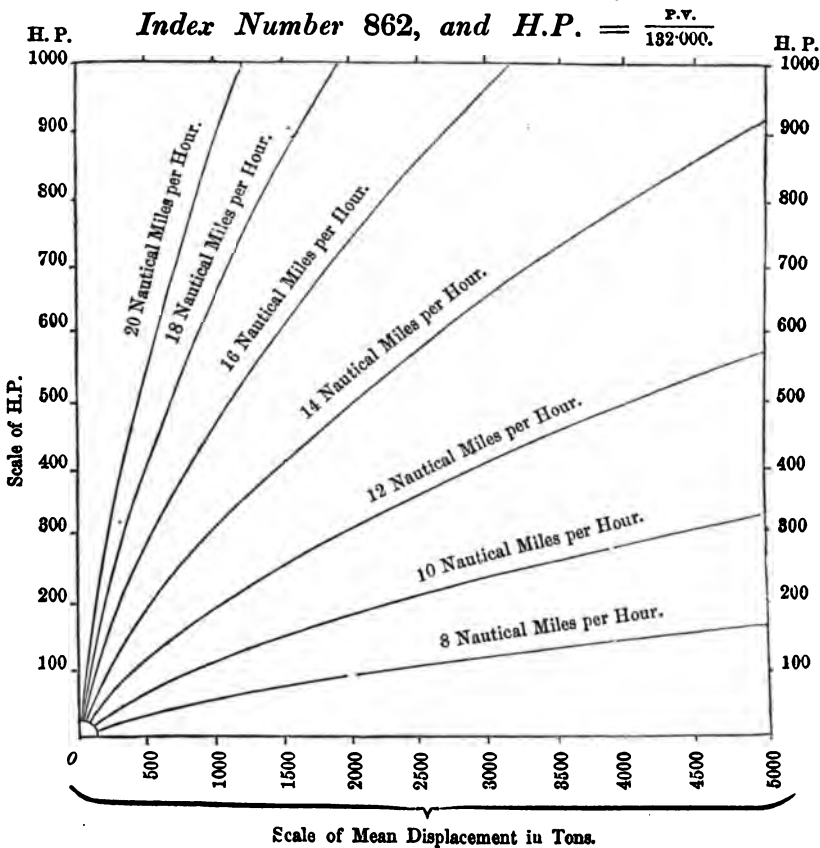


TABLE showing the number of REVOLUTIONS, per minute, which will be required in order that a SCREW-PROPELLER of a GIVEN PITCH may advance at a GIVEN SPEED (slip not included).

SPEED PER HOUR		PITCH OF SCREW IN FEET, (<i>Exclusive of any allowance for Slip</i>).																										
		2	2½	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
N. M.																												
5	253	203	169	127	101	84	72	63	56	51	46	42	39	36	34	32	30	28	27	26	24	23	22	21	20	19	19	
6	304	243	203	152	122	101	87	76	68	61	55	51	47	44	41	38	36	34	32	30	29	28	26	25	24	23	23	
7	355	284	237	177	142	118	101	89	79	71	65	59	55	51	47	44	42	39	37	35	34	32	31	30	28	27	26	
8	406	324	270	203	162	135	116	101	90	81	74	68	62	58	54	51	48	45	43	41	39	37	35	34	32	31	30	
9	456	365	304	228	183	152	130	114	101	91	83	76	70	65	61	57	54	51	48	46	43	41	40	38	37	35	34	
10	507	406	338	253	203	169	145	127	113	101	92	84	78	72	68	63	60	56	53	51	48	46	44	42	41	39	38	
11	558	446	372	279	223	186	159	139	124	112	101	93	86	80	74	70	66	62	59	56	53	51	48	46	45	43	41	
12	608	487	406	304	243	203	174	152	135	122	111	101	94	87	81	76	72	68	64	61	58	55	53	51	49	47	45	
13	659	527	439	330	264	220	188	165	146	132	120	110	101	94	88	82	78	73	69	66	63	60	57	55	53	51	49	
14	710	568	473	355	284	237	203	177	158	142	129	118	109	101	95	89	84	79	75	71	68	65	62	59	57	55	53	
15	760	608	507	380	304	253	217	190	169	152	138	127	117	109	101	95	89	84	80	76	72	69	66	63	61	58	56	
16	811	649	541	406	324	270	232	203	180	162	147	135	125	116	108	101	95	90	85	81	77	74	71	68	65	62	60	
17	862	690	575	431	345	287	246	215	192	172	157	144	133	123	115	108	101	96	91	86	82	78	75	72	69	66	64	
18	913	730	608	456	365	304	261	228	203	183	166	152	140	130	122	114	107	101	96	91	87	83	79	76	73	70	68	
19	963	771	642	482	385	321	275	241	214	193	175	161	148	138	128	120	113	107	101	96	92	88	84	80	77	74	71	
20	1014	811	676	507	406	338	290	253	225	203	184	169	156	145	135	127	119	113	107	101	97	92	88	84	81	78	75	

NOTE.—To compensate for SLIP the Revolutions of the Propeller may be increased about 10 per cent.

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OCEAN STEAMERS.

ON the occasion of a recent discussion in Parliament, a Member of the Council of the Institution of Civil Engineers is reported to have stated that, at a meeting of that body, "*Mr. ANDERTON had warned them against extending the size of Ships, as, beyond a certain size, the Ship would carry little else than its own fuel, and the speed would not be increased.*"—*Times*, 28th Feb. 1854.

This statement has evident reference to the remarks made by me, Mr. ATHERTON, in a recent discussion at the Institution of Engineers on the Capability of large Steamers; and this absurd version of the proceedings has been so promulgated and erroneously attributed to me, that I find it professionally due to myself to declare that it indicates a total misapprehension of the opinions, not only expressed, but written and delivered in by me for record at the Institution of Engineers on the occasion referred to; moreover, I feel myself called upon to protest against the proceeding, that any Member of the Council of Engineers should thus take advantage of his position as a Member of Parliament to re-agitate and pervert in Parliament a matter that has been the subject of protest and memorial on my part as respects the proceedings thereon of the Council of the Institution, and of consequent correspondence between the Council and myself; which correspondence had, as I supposed, been brought to a conclusion. Under these circumstances, I have no means of refuting the perversion of my professional opinions on the Capability of Ocean Steamers, which has thus been promulgated by a MEMBER of the COUNCIL of the INSTITUTION, other than that of publishing the following statement of my remarks as handed in by me for record at the Institution, together with the subsequent memorial which I addressed to the Council on the subject of this discussion; to which documents I have now added further remarks on the Capabilities of the large class of Ocean Steamers, to which public attention is being directed, as compared with vessels of ordinary size.

CHAS. ATHERTON.

WOOLWICH DOCKYARD,
20th April, 1854.



INSTITUTION OF CIVIL ENGINEERS,

15TH NOVEMBER, 1853.

DISCUSSION PROPOSED BY THE COUNCIL OF THE INSTITUTION “ON THE CAPABILITIES OF THE PROPOSED LARGE CLASS OF STEAMERS.”

MR. ATHERTON observed, that for the purpose of discussion it became necessary to particularize the obligations of the respective projects under consideration, and he presumed that the “*large class of steamers*” alluded to in the programme of proceedings had reference to the following projects now before the public, viz. :—

- 1st. The project favourably noticed by a Committee of the House of Commons for effecting the passage between Holyhead and Kingston (a passage of 64 statute miles) at a postal speed of $22\frac{1}{2}$ statute miles per hour ; the packet to be established for that purpose being proposed to have a displacement of 2,700 tons, and to be capable of attaining a maximum speed of 25 statute miles an hour, the intended Engines being denominated 1,600 Nominal H.P., but to be constructed for working up to 8,000 Indicated H.P.
- 2nd. The project now said to be undertaken by American Constructors to establish a communication between New York and Liverpool in 6 days ; the length of passage being about 3,250 nautical miles, and, therefore, demanding an average speed of 22 nautical miles an hour.
- 3rd. The project said to be undertaken in London for establishing a Steam Ship communication between England and Calcutta by vessels capable of carrying sufficient fuel for the whole voyage to Calcutta and back (being about 25,000 nautical miles), *without re-coaling*, at the promised average speed of 15 nautical miles an hour.

In the first place, Mr. ATHERTON observed on the necessity of investigating these projects with reference to the *best known example of already realised Steam Ship Capability*, rather than with dependence on any promissory, but, hitherto, not realised, scale of constructive improvement; that, in order to determine the Index Number or co-efficient (C) indicative of the relative degrees of constructive efficiency of different Steam Ships in regard to their locomotive capabilities, he (Mr. ATHERTON) had adopted the formula $\frac{v^3 \times D^{\frac{3}{2}}}{H.P.} = (C)$, or, Rule, multiply the cube of the velocity (v^3) by the cube root of the square of the Displacement ($D^{\frac{3}{2}}$), and divide by the actual working power (H.P.), by which Rule the relative degrees of locomotive capability of numerous ships, both in the Royal Navy and Merchant Service, had been tested; and whereby it has been found that the co-efficient or Index Number (C), as determined by the above Rule, was greater in the case of H. M. steam-sloop RATTLE than in the case of *any other ship whatever*, whether in the Royal Navy or Merchant Service, that had hitherto come under his observation; and that, therefore, he (Mr. A.) regarded the constructive type or form of the hull of RATTLE, and the co-efficient or number indicative of efficiency deduced therefrom, as the best realised data whereby to calculate the requirements for any contemplated service, such, for example, as the size of ship and power of engines required to fulfil the respective conditions of the projects above referred to. Adopting, therefore, this rule, and basing his calculations on the actual performance of H. M. steam-sloop RATTLE, he (Mr. A.) had constructed a series of Tables for each of the three projects, assuming that Steam Ships built of iron, or wooden Ships built on the diagonal principle, *may be constructed of any required size*; assuming also, that the weight of hull and equipment would not exceed 40 per cent. of the Load-line Displacement; also, that the total weight of the engine equipment would be 5 cwts, per Indicated H.P., of 33,000 lbs., raised 1 foot per minute, or 1 ton per Nominal H.P., of 132,000 lbs., raised 1 foot per minute; such being, very nearly, the actual weight of machinery in various examples of *present* marine engine practice; and, that the consumption of fuel need not exceed the rate of $4\frac{1}{2}$ lbs., per hour, per Indicated H.P.; or 4 cwts. per day, per Nominal H.P., of the unit 132,000 lbs., raised 1 foot per minute; which is about the present minimum rate of marine engine consumption, the engines working up to their ordinary duty.*

* The *extreme* limit of SPEED capable of being achieved by a steam-vessel of given size, will, of course, be dependant on the lightness of the hull and equipment, lightness of machinery per H.P., economy of consumption of fuel per H.P., and on the construction of the hull and the engine adaptation thereto, being such as to give a high rate of locomotive performance. These are subjects of practical construction; and it is impossible to assign any definite limits to promissory improvements, or to the hazards that may be recklessly incurred in the pursuit of fame by sacrificing strength to the attainment of lightness; but, as regards each of the above-mentioned particulars, the assumed data on which the Tables have been calculated, are believed to be favourable for the attainment of a high result, and such as have rarely, if ever, been combined in any one ship. It is therefore submitted that the results indicated by these Tables are of the highest order that present practice will justify being *calculated* upon, however sanguine may be the opinion as to the practicability of these results being surpassed.—(See "*Steam Ship Capability*," page 38.)

Calculating the requirements of project, No. 1, *on the above data*, Mr. ATHERTON came to the conclusion that a vessel of about 2,750 tons' Displacement, as proposed to Parliament, would not carry engines of greater weight than 1,375 tons' weight, working up to 5,500 *Indicated H.P.*; the maximum speed of which may not be expected to exceed 21 statute miles an hour; and that, to attain the *maximum* speed of 25 statute miles per hour, as required for the average postal speed of $22\frac{1}{2}$ miles per hour, the Displacement of the vessel would require to be not less than 13,000 tons, the engines would require to be 26,000 *Indicated H.P.*, and the cost of the Ship, complete, would probably not be less than £533,000. Mr. ATHERTON, however, observed that the weight of 5 cwt. per *Indicated H.P.* is probably three times the weight which is involved in the present construction of railway locomotive engines, and though he would not venture to anticipate that the weight of marine engine machinery can be advantageously reduced to the scale of railway locomotive practice, he expressed the opinion that it has hitherto been only the prejudices of the public against high pressure steam on board ship, and, possibly, the trammels of legislative intervention, which have prevented marine machinery *for short passages*, like that now under consideration (*viz.*, 64 statute miles), approximating, as regards *weight*, more closely to the railway locomotive principle and practice; and that if these difficulties be removed in the case now referred to, and the weight of marine engines be reduced to 3 cwt. per *Indicated H.P.*, then a vessel of 2,750 tons' Displacement, as proposed for this scheme, would carry engines of 1,350 tons' weight working up to about 9,000 *Indicated H.P.*, and there would be about 200 tons to spare for cargo and coal; which power may be expected to propel the vessel at the maximum speed of 25 statute miles per hour, or the proposed average postal speed of $22\frac{1}{2}$ statute miles, and the cost of the vessel, on the same data as before calculated on, would probably not exceed £156,500, being within the limit proposed to Parliament as the probable cost of one vessel capable of fulfilling the proposed postal requirement of $22\frac{1}{2}$ statute miles per hour on the 64 mile passage referred to. he (Mr. A.), therefore, regarded this project as mechanically practicable, inasmuch as the consumption of fuel on *so short a passage*, namely, 3 hours, does not materially affect the calculation.

On project, No. 2, namely, the performance of a passage of 3,250 nautical miles in 6 days, or, at the continuous speed of 22 nautical or $25\frac{3}{4}$ statute miles an hour, Mr. ATHERTON again referred to the Series of Tables which he has constructed on the data of *existing practice* before referred to, irrespective of hitherto *not realised mechanical improvements*, showing the progressively increasing size of vessel that would be required to perform a passage of 3,250 nautical miles at different rates of speed progressively increasing from 10 nautical miles per hour up to the proposed speed of 22 nautical miles per hour; from which it appears that a vessel of 2,500 tons' Mean Displacement, or 2,750 tons' Deep-draught Displacement, propelled by engines working up to 852 *Indicated H.P.*, may be expected to attain the speed of 10 nautical miles

per hour, and, therefore, to perform a passage of 3,250 nautical miles in 13 days, and have available Displacement for about 1,000 tons' weight of cargo ; but that, to perform the passage of 3,250 nautical miles at the accelerated speed of 22 nautical miles per hour, as required for the proposed 6 days' passage, it would, *on the data of present practice*, require a ship of 60,000 tons' Deep-draught Displacement, propelled by engines working up to 66,904 Indicated H.P., to perform the proposed service, even though the course of the vessel should always be favoured with a *non-obstructive* wind or current, and the Displacement available for cargo would be about 3,000 tons only.

Mr. ATHERTON noticed, that for high speed and long passages such as this (if a passage of 3,250 nautical miles can now-a-days be called long), engine improvement as to lightness may not be so available as for short passages of only 2 or 3 hours' duration ; and, moreover, that the advantage of such reduction of engine-weight per H.P. gradually becomes less appreciable in proportion to the length of passage without re-coaling, unless the *consumption of fuel per H.P.* be also in like manner reduced, of which he (Mr. A.) is not aware of any existing example below the consumption of $4\frac{1}{2}$ lbs. per Indicated H.P. per hour as herein calculated upon. He, therefore, regards this project for performing a passage of 3,250 nautical miles in 6 days as involving the Mercantile question of investing about £1,500,000 in the equipment of a single vessel, but he does not know whether such an investment has been contemplated by the promoters of the scheme.

On project, No. 3, namely, the performance of a voyage from England to Calcutta and back at the *average speed of 15 nautical miles an hour, carrying coal for the whole voyage of about 25,000 nautical miles*, Mr. ATHERTON observed, that after the elucidation elicited on the previous question as to the passage of 3,250 miles at 22 miles an hour, requiring a ship of 60,000 tons' Displacement, he would commence the investigation of this project for steaming 25,000 nautical miles at the average speed of 15 nautical miles per hour, without re-coaling, by examining whether a vessel even of 100,000 tons' Displacement (being about 20 times the capacity for Displacement of H. M. steam-frigate AGAMEMNON) would, *on the data of existing practice as before referred to*, fulfil the requirements of the proposed project, and he came to the conclusion that a steam-vessel of this size might perform the voyage of 25,000 miles, without re-coaling, at the reduced average speed of 14 nautical miles per hour, but the Displacement for cargo would be inappreciable. The engine-power required even for this reduced speed of 14 nautical miles per hour would be 27,532 Indicated H.P., the consumption of fuel would be nearly 1,400 tons per day, and the cost of the ship and engines would probably amount to two millions ; that is, if the ordinary averages of calculated expenditure admit of being approximately applied to so unprecedented a hypothesis.

Presuming, therefore, that this project of carrying coal from England to Calcutta in a *sufficiently surplus quantity to bring the ship back again at the*

average rate of 15 nautical miles an hour on the whole voyage of 25,000 nautical miles would not bear the test of Mercantile investigation as respects its *economy*, for which object the scheme of taking coal from England for the whole voyage out and home has been proposed ; Mr. ATHERTON proceeded to observe that if the distance, without re-coaling, were reduced to 12,500 *nautical miles*, by re-coaling at Calcutta for the home passage, then a ship of 25,000 tons' Mean Displacement, with a Deep-draught Displacement of 37,000 tons, might (wind and current excepted) perform the passage of 12,500 nautical miles at the speed of 15 nautical miles per hour, but the Displacement available for goods and cargo would, *as regards weight*, be inappreciable ; the vessel, presuming it to be constructed on a type *not inferior* to that of RATTLE before referred to, would require about 13,400 Indicated H.P., and the cost would probably amount to £600,000. Still, however, it may be expected that though the ship may be capable of a *maximum* speed of 15 nautical miles per hour, the influence of wind and weather would reduce the *average* speed to about 15 statute miles, or 13 nautical miles, per hour, which reduction of speed together with re-coaling at Calcutta altogether alters the conditions of the problem as set forth in the original prospectus of the project under consideration.

In conclusion, Mr. ATHERTON deprecated the idea of involving Commercial Investments in projects, the conditions of which may not be capable of being substantiated, and, as on this principle he conceived that every project *should stand or fall by the terms of the PROSPECTUS whereby it may have been brought before the Public*, he considered it unnecessary to prosecute the enquiry as to the extent to which the project of steaming 25,000 nautical miles at the *average speed of 15 nautical miles an hour without re-coaling* must be modified before it would be reduced to a condition of Mercantile feasibility.*

* The foregoing summary of the remarks expressed by Mr. Atherton at the Meeting on the 15th November was, at the request of the Secretary, handed in by Mr. A. on the 18th November. The discussion on Ocean Steamers was again brought forward at the ensuing Meeting, on the 22nd November, subsequently to which Meeting, the private press report of proceedings was issued; the subject was again notified for further discussion on the 29th November, when Mr. Atherton attended and PROTESTED against the record on this discussion, as promulgated by the PRIVATE PRESS REPORTS thereof, but Mr. A. was not permitted to vindicate his disputed statements, as recorded by him on the 18th, nor was any notice taken in the subsequent private press report of the protest thus entered by Mr. A. in regard thereto, consequently, Mr. Atherton addressed the following Letter and Memorial to the President and Council of the Institution :—

TO THE SECRETARY OF THE INSTITUTION OF CIVIL ENGINEERS.

Woolwich Dockyard,

17th December, 1853.

MY DEAR SIR,

The private press reports of the proceedings of the Institution of Civil Engineers on "the proposed large class of Steamers" having been promulgated without any notice being taken of the PROTEST made by me at the Meeting on the 29th November in regard to the records on this discussion, I beg to forward herewith a MEMORIAL on the subject of the proceedings referred to, requesting that you will be pleased to hand it to the Council at their first meeting. I also beg to claim the privilege, to which I believe I am entitled, of having this Memorial duly submitted to a Meeting of the Institution, and *literally* recorded; observing, also, that as the subject of this discussion has been publicly promulgated by the private press in a way that I conceive to be incorrect and professionally prejudicial to myself, I purpose giving publicity, should occasion so require, to these and to any other remarks I may have to make on the subject referred to.

I remain, my dear Sir,

Yours truly,

CHARLES ATHERTON.

MEMORIAL

BY

CHARLES ATHERTON

TO

THE PRESIDENT AND COUNCIL AND MEMBERS

OF THE

INSTITUTION OF CIVIL ENGINEERS.

*Woolwich Dockyard,
17th December, 1853.*

GENTLEMEN,

The Institution of Civil Engineers, at their meeting on the 8th November last, were pleased to take up the subject of a paper presented to the Institution by Captain Andrew Henderson (Hon. East India Company's Service), "On the Speed and other properties of Ocean Steamers, and on the Measurement of Ships for Tonnage;" in the discussion on that subject it was remarked by a Member of the Institution that, in proposing any new system of measurement, it is desirable that the *especial object* in view should be expressly stated. Concurring, as I cordially did, in the foregoing remark, I brought before the notice of the meeting, that if a complete scale of Displacement were regularly supplied by Ship Builders, or taken by official authority, it would afford an elementary datum of primary importance for judging of the comparative locomotive properties of different types or forms of Ship, whereby the relative degrees of *scientific talent* displayed in the construction of Steam Ships in a dynamical point of view might, on trial of the vessels' speed and power, be approximately ascertained, a *RIVALRY OF TALENT* would thus be created conducive to scientific progress in Steam Navigation similar to what has occurred in Railway Engineering, producing Mercantile results which would, in my opinion, be highly advantageous to the public interests. I now beg to observe that *no notice* was taken of these remarks in the *private press report* of proceedings on the 8th November, which, under

the auspices and control of the President and Council, is printed and circulated weekly for the information of the Members of the Institution.

Subsequently to the meeting on the 8th November above referred to, the President and Council were pleased, by their Circular Letter of the 9th November, to suggest that the attention of Members, at their ensuing meeting on the 15th November, might be especially directed to "The advantages and disadvantages of the PROPOSED LARGE CLASS OF STEAMERS, with respect to their scientific construction, their capabilities for navigation, and their commercial economy;" accordingly, at the meeting of the Institution on the 15th, I submitted my views on the subject *thus especially proposed and put forward by the President and Council themselves for discussion*, particularly specifying the projects to which I presumed that the requisition had reference, and to which my remarks and calculations applied. The usual weekly private press report of this day's proceedings was not issued, (thus the statements made by me on the 15th were suppressed,) but the subject was again discussed at the subsequent meeting on the 22nd, and again notified for further discussion on the 29th. On the 29th, therefore, I attended for the purpose of responding to remarks which had been circulated by the *private press report* of proceedings on the 22nd, calling in question the *authenticity* of the suppressed statements made by me on the 15th, the President, however, on his taking the chair on the 29th November, instead of *continuing* the discussion "on the large class of steamers," *as notified by the circular*, summarily announced the discussion on this part of the subject *closed*; whereupon, I PROTESTED AGAINST THE PARTIAL RECORDS OF PROCEEDINGS AS PRINTED AT THE PRIVATE PRESS AND ISSUED TO THE MEMBERS OF THE INSTITUTION; basing my protest on the following grounds, viz. :—

That the purport of the remarks submitted by myself to the meeting on the 8th November had been entirely excluded from the private press report; also, that the usual weekly private press report of the proceedings on the 15th November had not been issued at all previously to the meeting of the 22nd, and that, in consequence of such suppression of my statements, misapprehensions had arisen at the meeting on the 22nd of November as regards the facts to which I had referred, as well as in regard to the limitations on which I had based my calculations, and also as respects the sense that pervaded my sentiments on the subject of the proposed large class of steamers especially referred to; on all which points I expressed my desire to offer full explanation, but I was prevented from so doing on the grounds that the discussion had now been closed, as before stated, from the chair. In consideration, however, of the urgency with which I claimed to be heard, the President was pleased so far to accede to my request as to concede that I should, under the circumstances referred to, be permitted to read the written statement that, at the request of the Secretary to the Institution, I had myself drawn up and handed to him on the 18th November, as being the purport of the remarks expressed by me at the

previous meeting on the 15th November, in order that a summary thereof might appear as usual in the private press weekly report to be issued previously to the 22nd; such, indeed, having been the very purpose for which, at the request of the Secretary to the Institution, I had prepared and delivered the statement which was, nevertheless, suppressed. Now, inasmuch as this subject has been brought to a close by the decision of the President and Council without having been by any means exhausted on the part of the Members of the Institution, and closed under PROTEST on my part as to the private press reports, of which PROTEST, or of the grounds thereof, *no notice whatever has been taken in the private press reports of proceedings on the 29th November*, I now beg to present, in the form of a MEMORIAL for record at the Institution, and to be otherwise used as the case may require, the explanation which I was prepared to bring before the Institution at their meeting on the 29th November in justification of my previous statements of the 15th November, which, though suppressed, had, nevertheless, been called in question by the subsequent private press report of proceedings on the 22nd.

In the first place,—I beg to explain that, individually, I have taken up this subject purely as a mechanical question of steam-ship constructive efficiency in a *dynamical* point of view. I have not touched the question as regards the Mercantile, or the Statistical, or the Nautical considerations, which, in their respective departments, may bear powerfully on the case; and, as an Engineer, I have limited my estimate of "Stock Cost" merely to the probable investment that would, in my opinion, be incurred in the fitting out of a single ship, if constructed of dimensions *capable of fulfilling the required conditions*, of the project as set forth by its prospectus.

The statements and calculations submitted by me to the Institution on the 15th November were avowedly based on the type and form of H. M. screw steam-sloop RATTLER, the locomotive efficiency of which vessel, when tested by the formula $\frac{V^3 D^{\frac{5}{4}}}{\text{IND. H.P.}}$ was referred to as being, to the best of my knowledge, unsurpassed by that of any vessel of the present day, either in the Royal Navy or in the Merchant Service; and the data on which my calculations were made were particularly set forth and referred to. Nevertheless, by the weekly private press report of proceedings of the Institution on the 22nd November, page 4, it is set forth, in reference to the suppressed statements which I made on the 15th, that "*the data were not given for selecting that vessel*," and also, "that the RATTLER had not performed a series of long voyages under every variable line of immersion, or under such changes of weather and states of the sea as to furnish data for such important deductions;" and again, by the private press report of proceedings on the 29th November, page 3, it is set forth that "it must be clearly understood that the RATTLER, which had been used as the type, was built during the most depressed period (scientifically) of construction in H. M. Dockyards."

Now, as regards having based my calculations on the type of *form* exemplified by H. M. steam-sloop RATTLER, the reasons for my selection of that vessel were fully referred to in my statement of the 15th, and may be re-stated and further extended as follows:—

1st. Because, on referring to the published Admiralty record of the test-trials of the screw ships of the Royal Navy, as printed and issued by the Admiralty in May, 1850, (in which record the locomotive performance or efficiency of each ship has been designated by a numeral co-efficient, or index number of efficiency, deduced from the formula $\frac{V^3 D^{\frac{5}{2}}}{\text{IND. H.P.}}$) I found that H. M. steam-sloop RATTLER stood at the head of the list as surpassing all screw ships then in the Royal Navy.

2nd. Because, having recently availed myself of opportunities for comparing by the same rule, H. M. steam-sloop RATTLER with other vessels, both paddle-wheel and screw, in the Merchant Service as well as in the Royal Navy, including H. M. steam-packet BANSHEE (paddle-wheel), still I have never yet met with any vessel that, on combination of the elements of DISPLACEMENT, POWER, and SPEED, by the rule referred to, has produced a numeral result indicative of a superior degree of locomotive efficiency to that attained by RATTLER.

3rd. Because, amongst all the *newspaper* and other published reports of data derived from steam-ship trials, I have never seen any instance based on complete and duly authenticated trial, whereby it can be deduced by the rule or formula referred to that the locomotive efficiency of the RATTLER has, hitherto, been surpassed.

4th. Because, H. M. steam-sloop RATTLER, after 10 years' service in the Royal Navy, chiefly on *Foreign Service in all seas*, and subject to all the usual fluctuations in point of immersion, has proved herself to be a vessel of creditable sea-worthy properties for her class, thereby showing that the high degree of locomotive efficiency exemplified by the type of RATTLER has not been attained by the sacrifice of nautical trustworthiness.

5th. Because, H. M. steam-sloop RATTLER having been the first vessel exceeding a Displacement of 1000 tons to which the screw propeller was applied in the Royal Navy, and the precursor to the application of the screw to vessels of large size in the Merchant Service, I regarded it as an important subject for investigation why this ship, *although not originally constructed for a screw-vessel*, but converted in the year 1841 to a screw ship by a slight addition to her stern, should still, in the year 1853, appear at the head of the published lists of *steam-vessels* in regard to locomotive efficiency, as determined by the formula above referred to, based on *actual trial data* duly authenticated.

6th. Because, the peculiarities of this case of RATTLEB, though brought before public notice by the published records of the Admiralty in May, 1850, (which record has been re-published, for example, by BOURNE,) and especially referred to by myself in an Essay on MARINE ENGINE CONSTRUCTION, page 12, published by WEALE, London, in April, 1851, and again referred to by me in an Essay on STEAM SHIP CAPABILITY, page 18, published by GRANT, Woolwich, in March, 1853; of both which Essays I have presented copies to the Institution and distributed them extensively amongst Naval Officers and steam-ship constructors, still, notwithstanding this publicity, the superiority of RATTLEB has remained unchallenged, excepting by the general assumptions published in the *private press* report of proceedings at the Institution on the 22nd November, to which all reply on my part at the Institution of Engineers, even in justification of my statements, has been denied me and foreclosed.

7th. Because, the type of RATTLEB, although described by the private press report of the Institution as having been "*built during the most depressed period, scientifically, of construction in H.M. Dockyards,*" is nevertheless so far tacitly acknowledged to be remarkable, that certain eminent constructors of the present day have, as I understand, declined to guarantee, *under contract*, the re-production of equal dynamic results, on the test of the formula referred to.

8th. Because, I regard it as a reasonable requirement that all contracts for steam-ships should include *some guarantee or other*, not only as to the size but also as to the DYNAMIC QUALITY of the steam-ship to be delivered under the contract, and for which, gold of a certain *weight* and standard QUALITY is to be paid. I believe that one mode of effecting the object of *contract guarantee* as to the dynamic *quality* of Merchant steam-ships would be approximately attained by means of the co-efficient or index number deduced by the formula $\frac{V^2 D^{\frac{2}{3}}}{\text{IND. H.P.}}$ from data derived from the actual test-trial performance of the vessel, and although H. M. screw steam-sloop RATTLEB was constructed in "1841," when, as would appear by the private press report of the proceedings of the Institution, "*H. M. Dockyards were, scientifically, in their most depressed condition,*" nevertheless, I believe it will be found that the co-efficient or index number indicative of the dynamic quality of that vessel is still the highest that any steam-ship constructor would now in "1853," be willing to admit *as the base of a steam-ship contract*.

9th. Because, the adoption of some guarantee such as that above suggested would, by affording the means of comparing the "*dynamic qualities*" of steam-ships, at once lead to *professional rivalry* that would greatly promote the science of steam-ship construction and be conducive both to Naval efficiency and Mercantile economy of transport: considerations of high public importance.

Such are the grounds on which I assumed the TYPE of RATTLER as the base of my calculations, and it will be a subject of Mercantile congratulation when steam-ship constructors shall not merely achieve an occasional superior dynamic result, but constantly guarantee its equal. Investigations and calculations such as I have advanced required, as an assurance of their practical application, to be based on *some existing type of form*, and, for the reasons above stated, it appeared to me that the RATTLER, though constructed in "1841," still afforded in 1853 the most appropriate type of form on which I could base calculations on steam-ship capability according to an *already realised* and, as may be hoped, again realisable scale of performance. The sentiments with which I have regarded and still regard the case of the RATTLER are set forth at page 18 of my Essay on *Steam Ship Capability* (published by GRANT, Woolwich, 1853,) in the following terms :—" Her Majesty's steam-sloop RATTLER having now held this pre-eminent position for 12 years, it is, of course, to be expected that, amongst the multiplicity of rivals of modern construction and the confident pretensions to superiority advanced successively in favour of each ship of the most recent build, the RATTLER must soon assume a secondary place : until, however, such superiority shall be realised, the RATTLER may be regarded as a *type of form* and of engine adaptation thereto worthy of the study (not slavish imitation) of steam-ship CONSTRUCTORS and the attention of steam-ship PROPRIETORS."

Now, as respects the "PROPOSED LARGE CLASS OF STEAMERS" to which the attention of members was directed by the Circular of the President and Council, and to which I addressed myself at the meeting on the 15th November, I considered it indispensable that I should specify "*the particular projects*" which I presumed to be specially referred to as the subject of discussion, namely :—

1st. The project favourably noticed by a Committee of the House of Commons for effecting the passage between Holyhead and Kingstown (a distance of 64 statute miles) at a postal speed of 22½ statute miles per hour.

2nd. The project now said to be undertaken by American constructors to establish a communication between New York and Liverpool in 6 days, the length of passage being assumed at 3,250 nautical miles, and therefore demanding an average speed of 22 nautical miles per hour.

3rd. The project said to be undertaken in London for establishing a steam-ship communication between England and Calcutta by vessels to be *capable of carrying sufficient fuel for the whole voyage to CALCUTTA AND BACK*, being a voyage of about 25,000 nautical miles, *without re-coaling*, at the promised average speed of 15 nautical miles an hour.

No objection, be it observed, was taken by the President and Council at the meeting on the 15th to the foregoing specific designation of projects

which I thus particularized as being THE PROJECTS to which I presumed that the Circular of the President and Council referred. The first two projects, though the subjects of the chief portion of the statements addressed by me to the meeting on the 15th November, have not been noticed at all by subsequent speakers or in the private press report of proceedings, and, therefore, I make no further allusion to them ; but, as regards the 3rd project, namely, the projected voyage of 25,000 nautical miles, *without re-coaling*, at the average speed of 15 nautical miles per hour, as proposed by the EASTERN STEAM NAVIGATION COMPANY, the private press report has altogether mis-stated the obligatory conditions announced by the PROSPECTUS of this project by referring to them in the following terms:—

“It was assumed that when it was stated a large steamer was intended to run to India or Australia and back, without re-coaling, it was only meant that she would carry enough coal to avoid detention at the *intermediate* ports.”

By this assumption, the correctness of my statements as to the published conditions of the prospectus of the Eastern Steam Navigation Company has thus, on the face of the Institution PRIVATE PRESS report, been directly questioned, and my proffered vindication thereof having been refused, it now only remains for me to justify my statements by quoting the printed prospectus of the Eastern Steam Navigation Company as promulgated and presented at a general meeting of the Proprietors, August 6th, 1853, from which I extract the following announcements:—

PAGE 3.—“Your ships will *escape the great cost of taking in coal AT A FOREIGN STATION*: your ships will take their *whole amount of coal for the voyage FROM NEAR THE PIT’S MOUTH at a rate not exceeding, for the best quality, 12s. to 14s. per ton.*”

PAGE 4.—“By this great speed (15 knots an hour) the voyage between ENGLAND and INDIA, by the Cape, will be reduced to from 30 to 33 days, and between ENGLAND and AUSTRALIA to 33 or 36 days.”

PAGE 7.—“Your Directors think it right to state that the result of their calculations is, that after making the most ample allowance for working expenses, depreciation, wear and tear, and insurance, a surplus remains equal to 40 per cent. per annum upon the capital invested.”

Such are the terms of the prospectus on which I made the statement that the ships for this project were to be coaled in ENGLAND for the whole voyage to CALCUTTA AND BACK, direct, and that the vessels were to be propelled at the average speed of 15 nautical miles per hour; and it is now important to observe that the mechanical capability of the proposed ships to carry coal

FOR THE WHOLE VOYAGE at the average speed of 15 nautical miles per hour, to be shipped from "*near the pit's mouth at a cost not exceeding 12s. to 14s. per ton for the best quality,*" was prominently put forward in the prospectus as one of the ostensible grounds of economy in the great item of coal on which the *promised dividend of 40 per cent. per annum* was held out to the Shareholders. It is the mechanical fulfilment of these conditions, on which the said promised dividend of 40 per cent. per annum has been calculated, that constitutes the question which I undertook to discuss on the base of *existing steam-ship practice*, irrespective of promissory improvements not yet practically realised.

I conceive that I need not now, in this Memorial, recapitulate the statements and calculations made by me at the meeting of the 15th on the subject of this project: suffice it to say that, assuming the index number of the RATTLER as the base of my calculations, and taking the consumption of fuel at $4\frac{1}{2}$ lbs. per indicated H.P. per hour, (which, I believe has not been surpassed by the best examples of marine engine practice of the present day,) I came to the conclusion that the size of vessel that would be required for the due fulfilment of the conditions of the project, *as announced by the PROSPECTUS* of the Eastern Steam Navigation Company, would, probably, be not less than 100,000 tons' Displacement! and that the whole CAPITAL of the Company, as proposed by the prospectus, namely, £2,000,000, would, probably, be absorbed in the construction of a *single vessel, if constructed of the stupendous size that would, according to my calculations, be indispensable for the performance of 25,000 nautical miles without re-coaling, at the average speed of 15 nautical miles per hour.* A written summary of the remarks expressed by me at the meeting on the 15th November setting forth the data and grounds of my calculations was, as before stated, prepared by me at the express desire of the Secretary of the Institution, and handed to him by myself on the 18th November; and it is to the total suppression of that written document expressive of my sentiments, whilst the sentiments of others having apparently a more favourably tendency in support of the project referred to, and questioning my veracity in order to support that view, have been circulated by the PRIVATE PRESS of the Institution, that I attribute much of the misunderstanding and perversion that has arisen in regard to my opinions as to the undoubtedly superior dynamic capability of large ships as compared with smaller vessels.

As an Engineer, I am not opposed to the construction of large ships, as has been erroneously imputed to me, but I have questioned the fulfilment of the MECHANICAL CONDITIONS as respects the *combination* of a 15 knot speed with a 25,000 mile voyage WITHOUT RE-COALING, on which this EASTERN STEAM NAVIGATION PROJECT appears to have been founded.

My sentiments as to the advantages of large ships in a mechanical point of view have been fully set forth in my engineering practice, as the constructor of the engines of the "DON JUAN," in "1834," the largest engines of their day, and in the publication that I have issued on Steam Ship Capability, in 1853, I have thus both practically and theoretically declared myself in favour of the

superior capabilities of large ships as respects either **SPEED** or **DISTANCE**, but I desire to forewarn steam-ship proprietors of the Mercantile disappointment to which extravagant expectations as respects the *combination* of high speed and great length of voyage, **WITHOUT RE-COALING**, by the mere agency of size, will, in my opinion, inevitably lead. Constructively, I recognise no limit as to size but that which may be dictated by **MERCANTILE** and **NAUTICAL** considerations; and I believe that my views, as stated by myself, have been expressed in a manner that would not have been misunderstood, had they not been promulgated in a perverted sense by the **PRIVATE PRESS REPORTS** of the Institution of Engineers.

CHARLES ATHERTON.

FURTHER REMARKS.

(Not included in the foregoing MEMORIAL to the Institution of Engineers.)

Mr. ATHERTON avails himself of this opportunity to elucidate more fully the views which he entertains in demonstration of the superior dynamic capabilities of large ships, and which he was desirous to bring before the Institution of Engineers at their meeting on the 29th November last, had further remark on his part been permitted. Continuing, therefore, our investigations, the following Tables (based on the formula $\frac{V^3 D^{\frac{1}{2}}}{\text{IND. H.P.}} = C$) will show definitely the comparative degrees of superior capability which, in a locomotive or dynamical point of view, and without reference to Mercantile or Nautical considerations, is the inherent property of increased magnitude; the comparison being made between ships of *similar* type of form, but differing only in *size*: the type now, as before, adopted as the base of the calculations being that of "RATTLEB," of which vessel, the co-efficient (C) deduced, with reference to the Indicated H.P. of 33,000 lbs. raised 1 foot per minute, is $C = 215.5$.

TABLE, No. 1, showing the **SUPERIOR CAPABILITY** of large ships, as indicated by a *progressively increasing rate of speed* corresponding to a progressively increasing size of ship; the proportion of Displacement to Power being assumed, in all cases, constant, namely, 2 tons' weight of Displacement to 1 Indicated H.P., of 33,000 lbs., raised 1 foot per minute:

Displacement. Tons.	Indicated H.P.	Speed. Knots.
5000	2500	12.27
10000	5000	13.25
20000	10000	14.31

Hence, it appears that the same PROPORTION of Power to Displacement which drives a ship of 5,000 tons Displacement at 12 knots an hour will drive a ship of 10,000 tons, on the same type of build, at 13 knots, and a ship of 20,000 tons at 14 knots per hour.

TABLE, No. 2, showing the SUPERIOR CAPABILITY of large ships as indicated by the progressively reduced ratio of *Power to Displacement*, whereby a constant speed is given to vessels of progressively increasing size; the calculation being made for the constant speed of 15 nautical miles an hour:

Displacement. Tons.	Speed. Knots.	Indicated H.P.	Ratio of Displacement to Indicated H.P.
5000	15	4569	100 to 91
10000	15	7252	100 to 72
20000	15	11518	100 to 57

Hence, it appears that to attain the speed of 15 knots an hour, a ship of 5,000 tons' Displacement requires 91 Indicated H.P. for each 100 tons' of Displacement; but a ship of 10,000 tons' Displacement, on the same type of build, requires 72 Indicated H.P. for each 100 tons' Displacement, and a ship of 20,000 tons on the same type of build will require only 57 Indicated H.P. for each ton of Displacement.

TABLE, No. 3, showing the SUPERIOR CAPABILITY of large ships as indicated by the progressively increasing distance capable of being run, without re-coaling, at a given rate of speed (say 15 knots an hour,) and with a given per centage of the Displacement appropriated to cargo (say 10 per cent)—see note:

Mid Passage Displacement. Tons.	Speed. Knots.	Indicated H.P.	Cargo (10 per cent. of Displacement). Tons.	Coal. Tons.	Distance, without re-coaling. Naut. Miles.
5000	15	4569	500	2716	4440
10000	15	7252	1000	6374	6555
20000	15	11518	2000	14244	9240

Hence, it appears that, at the speed of 15 knots an hour, and with 10 per cent. of the Displacement appropriated to Cargo, a ship of 5000 tons' Displacement will steam a distance of only 4,440 miles without re-coaling; but a ship of 10,000 tons, will under the same conditions, steam 6,555 miles without re-coaling, and a ship of 20,000 tons, will, under the same conditions, steam 9,240 miles without re-coaling, at the speed of 15 knots per hour.

NOTE.—In these Tables the weight of the hull and its equipment is assumed to be 40 per cent. of the Mid Passage Displacement; the weight of the engines and their equipment 5 cwts. per Indicated H.P., and the consumption of coal $4\frac{1}{2}$ lbs. per Indicated H.P. per hour.

TABLE No. 4, showing the SUPERIOR CAPABILITY of large ships as indicated by the *reduced consumption of fuel per ton of cargo* at which goods will be conveyed a given distance, without re-coaling, at a given speed; supposing, for example, that the distance, without re-coaling, is to be 3,250 nautical miles and the speed 10 nautical miles an hour:

Mid Passage Displacement Tons.	Speed. Knots an hour	Indicated H.P.	Distance Naut. Miles.	Coal. Tons.	Cargo. Tons.	Tons of Coal per Ton of Cargo.	Deep-draught Displacement Tons.
5000	10	1354	3250	884	2219	40	5442
10000	10	2149	3250	1403	4762	29	10701
20000	10	3411	3250	2227	10034	22	21113

Hence, it appears that, in the case of a 3,250 miles direct passage at 10 knots an hour, by increasing the size of the ship from 5,442 tons to 21,113 tons of Deep-draught Displacement, the consumption of coal per ton of cargo conveyed is reduced from $\frac{40}{100}$ down to $\frac{22}{100}$ being a reduction of nearly 50 per cent. in favour of the larger ship.

The foregoing Tables having thus illustrated the SUPERIOR CAPABILITIES of large ships as compared with smaller vessels for the performance of any special service under the same specific conditions of speed and distance without re-coaling, the following TABLE (No. 5) is intended to show how soon the admitted advantages which result from increased size become neutralized, if, on the strength of increased size alone, we undertake OBLIGATIONS which involve, on the part of the large ship, an increased rate of speed COMBINED with an increased distance, without re-coaling; to demonstrate which, we will assume that in the prosecution of a steam-ship project on a line of communication extending a distance of about 12,500 nautical miles (such, for example, as the line between England and Calcutta), it is intended to employ shipping to the extent of about 20,000 tons, to be propelled by steam-power in the proportion of 2 tons of Displacement to 1 Indicated H.P. The problem now is to determine whether, as respects SPEED and the consumption of COAL per ton weight of CARGO conveyed, the proposed service will be most advantageously performed by

SCHEME No. 1.

ONE VESSEL of 20,000 tons Mean or *Mid Passage* Displacement and 10,000 Indicated H.P., making the passage of 12,500 nautical miles direct, at the speed of 14.31 nautical miles an hour; or by

SCHEME No. 2.

TWO VESSELS of 10,000 tons' Mean or *Mid Passage* Displacement and 5,000 Indicated H.P., making the passage in 2 stages of 6,250 nautical miles, at the speed of 13.25 nautical miles an hour; or by

SCHEME No. 3.

FOUR VESSELS of 5,000 tons' Mean or *Mid Passage* Displacement and 2,500 Indicated H.P., making the passage in 4 stages of 3,250 nautical miles, at the speed of 12·27 nautical miles an hour.

It will be found by calculations *based on the data before referred to*, that the mutual relations of Displacement, Power, Speed, Length of Passage, Cargo, and Coals, which result respectively from the above-mentioned 3 Schemes of shipping, will be as represented by the following TABLE, No. 5 :—

Scheme.	Mean or Mid Passage Displacement.	Indicated H.P.	Speed per hour.	Distance 12500 Nautical Miles.	Steaming time.	Coal.	Cargo.	Coal per ton of Cargo.	Deep Displacement.
	TONS.		N. M.		D. H.	TONS.	TONS.	TONS.	TONS.
1	20000	10000	14·31	1 stage of 12500	36·10	17550	725	24	28775
2	10000	5000	13·25	2 stages of 6250	39· 8	9478	2381	4	12369
3	5000	2500	12·27	4 stages of 3250	44· 3	5316	1711	3	5664

From the above Table we observe the following results, namely :—

The steaming speeds by the above proposed 3 Schemes respectively will be at the rate of about 14, 13, and 12 nautical miles per hour : the steaming time at sea on the passage of 12,500 miles will be about 36, 39, and 44 days by the 3 Schemes respectively, and allowing 4 days for re-coaling the 10,000 tons' ship (Scheme No. 2) at the one intermediate station, and 2 days for re-coaling the 5,000 tons' ship (Scheme No. 3) at each of the three intermediate stations : then the whole time of passage between England and Calcutta by the 3 Schemes respectively would be 36 days, 43 days, and 50 days ; being 14 days shorter time of passage in favour of the one ship (Scheme No. 1) as compared with the 4 ships (Scheme No. 3) ; but the Mercantile sacrifice which attends this saving of 14 days by Scheme No. 1, as compared with Scheme No. 3, is, that by scheme No. 1, 17,550 tons of coal are consumed in the conveyance of only 725 tons of cargo, being at the rate of 24 tons of coal per ton of cargo, while each of the 4 ships of Scheme No. 3 consumes 5,316 tons of coal in the conveyance of 1,711 tons of cargo, being at the rate of 3 tons of coal per ton of cargo. Thus, notwithstanding the superior capabilities of large ships as compared with smaller vessels for performing any special service *on equal conditions* in regard to speed and distance without re-coaling (as shown by Tables 1, 2, 3, and 4,) we see, in the case before us (as shown by Table No. 5,) assuming each ship to make the

same number of passages per annum (for, the larger ships, though a shorter time at sea, will be detained the longer in port,) that the four ship Scheme, No. 3, as compared with the one ship Scheme, No. 1, is, under the different conditions as to speed and coaling stations above stated, capable of transporting between England and Calcutta nearly 10 times the aggregate weight of cargo per annum with one-eighth of the consumption of coal per ton of cargo conveyed, but with an admitted sacrifice of 14 days on the time of passage.

If, however, the consumption of fuel on board of ship be reduced from 4½lbs. per Indicated H.P. per hour, on which the foregoing calculations have been based, down to 3lbs. per Indicated H.P. per hour, which is theoretically possible, and, therefore, it is hoped, may be achieved, then, on the same principle of calculation and under the above stated conditions as to loss of time by Scheme No. 3, it would still be found that the four ship Scheme, No. 3, as compared with the one ship Scheme, No. 1, would transport about double the weight of cargo per annum between England and Calcutta with about one-half of the consumption of fuel per ton of cargo conveyed, but, as before stated, with an admitted sacrifice of 14 days on the time of passage.

The consumption of fuel per ton of cargo conveyed is, as one item of expense, perhaps the best criterion of the relative merits of different Schemes of Steam Navigation as respects Mercantile economy; and, on inspecting Table No. 5 with reference to this point, it will be observed that the 2nd and 3rd Schemes are very nearly on a par with each other, that is, under the assumed working arrangements of these Schemes as above set forth, a vessel of 5,664 tons Deep-draught Displacement fitted for steaming at 12 knots per hour, and re-coaling at intervals of 3,250 nautical miles, will be somewhat more economical than a vessel of 12,369 tons Deep-draught Displacement fitted for steaming at 13 knots per hour, and re-coaling at intervals of 6,250 nautical miles, and as compared with a vessel of 28,775 tons Deep-draught Displacement fitted for steaming at 14 knots per hour, and making the passage of 12,500 miles direct, without re-coaling at any intermediate station, the difference in point of freight economy, as indicated by the economy of coal per ton of cargo conveyed, is so greatly in favour of the smaller vessel, *time excepted*, that a vessel working under such conditions of 14 *knot speed* COMBINED with a 12,500 mile distance, without re-coaling, can only be regarded as a packet not profitably available for Mercantile cargo.

If, however, the ship for Scheme No. 1 be constructed for a Deep-draught Displacement of 26,000 tons, and be fitted for the *reduced* speed of 12 knots per hour, the direct passage of 12,500 miles would then occupy 44 days, the consumption of fuel at 3lbs. per Indicated H. P. per hour would be 12,000 tons, and the Displacement available for cargo would be 4000 tons weight, being at the rate of 3 tons of coal per ton of cargo conveyed, or about the same expenditure of coal per ton of cargo as that incurred by the 5,664 tons ship, (Scheme No. 3) steaming at the same speed, viz., 12 knots per hour, but

re-coaling at intervals of 3,250 nautical miles, and taking, including stoppages for re-coaling, 50 days for the passage ; being an admitted superiority of 6 days in favour of the direct passage of the Leviathan ship of 26,000 tons. The question is, whether this result, viz., the saving of 6 days by the Leviathan ship, will adequately compensate for the extraordinary requirements of its realization.

In all the foregoing statements, the mutual relations of *Displacement, Power,* and *Speed* have been calculated without reference to the influence of wind and current, which, indeed, may be regarded as obstructing the regular performance of a high speed service ; for, a favourable wind, such as might help a vessel steaming at 12 knots an hour (as in Scheme No. 3), may afford no aid or even oppose a vessel steaming at 14 knots an hour (as in Scheme No. 1) ; and an adverse wind will obstruct a vessel steaming at a high speed in a greater ratio than it would obstruct the low speed ship.

On these grounds, Mr. A. would again affirm the remark advanced in his Essay on *Steam Ship Capability*,* page 60, as follows :—

“It is presumed to have been sufficiently shown by the foregoing calculations and deductions therefrom (though avowedly based on approximate data), that extreme caution ought to attend all Mercantile steam-ship contracts in regard to the obligation of maintaining such a rate of STEAMING SPEED for a *long passage* as exceeds the rate at which the wind may be expected to partially co-operate with the steam power ; it is also presumed to have been shown how greatly it is to be apprehended that various projects now publicly promulgated, and confidently professing to undertake the regular performance of very long passages at high rates of speed (for instance, 15 knots an hour and upwards), are based on expectations not commercially justified by the relation which, at present, actually subsists between Steam-ship Displacement, Power, Speed, and cost of freight *per ton* ; at least, if the probability of the due fulfilment of such projects is to be judged of by the locomotive capability that has, hitherto, been practically realized by the most successful steam-vessels of the present day.”

In conclusion, Mr. ATHERTON would remark that Engineers must be struck with astonishment at the readiness with which capital still continues to be advanced in Great Britain for the prosecution of any enterprise however unprecedented in character or stupendous in point of ideal or material magnitude, provided only that it have the sanction of scientific authority. As a Member of the Institution of Civil Engineers, Mr. A. regards it incumbent on the Institution generally, and on its individual Members respectively, to promote to the best of their individual ability and conviction of the truth sound and realisable progress in science, as practically conducive to sound and profitable pecuniary investment, and to uphold the confidence with which Engineering as a profession embodied at

* The second issue of this work extended to meet the case of vessels of unprecedented magnitude, is now being published by GRANT, Woolwich.

the INSTITUTION is publicly honoured by endeavouring to moderate all such expectations on PROJECTS brought before the INSTITUTION as may appear on discussion to be based on questionable grounds in mechanical science. It is with this purpose that Mr. A., after having given his attention to the almost novel study of "Steam Ship Capability," as respects the combined relations of Tonnage, Displacement, Power, Speed, Length of Passage, Cargo, and Coal, in connection with different types of build and of engine adaptation thereto, and having already appeared before the public on this subject by his publications thereon, was induced to take part at the Institution of Civil Engineers in the discussion proposed by the Council themselves. "On the CAPABILITY of the proposed LARGE CLASS OF STEAMERS;" and holding the opinion that the undoubtedly superior dynamic capability of large ships as compared with smaller vessels will be most advantageously developed by the superior PECUNIARY ECONOMY at which any given service will be performed on *equal conditions as to speed and distance, without re-coaling*, rather than by the TIME-ECONOMY resulting from the combination of a *high rate* of speed with an *increased length of passage, without re-coaling*, as proposed by the prospectus of the project especially under consideration; feeling also that the public generally are little aware of the practical difficulties which attend the plausible combination of high speed with great distance without re-coaling, he (Mr. A.) thought proper, for the reasons above stated, not to remain silent, but to announce his views at the Institution. Mr. A. is open to any equally comprehensive elucidation of the subject which other Members may have to advance; but he regrets having experienced that the action of the Institution in regard to this discussion on the "Capability of Large Steamers," as virtually brought before the public by its PRIVATE PRESS REPORTS, and by the action of an individual MEMBER of the COUNCIL, beyond the sphere of the INSTITUTION itself, (see *Times*, 28th Feb. 1854) has tended to compromise his professional character, and has rendered the foregoing exposition on his part a matter of personal obligation; unwelcome, perhaps, to some individuals connected with the projects referred to, towards whom Mr. A. entertains the highest personal regard and the most sincere good wishes for their professional success.

CHARLES ATHERTON.

WOOLWICH DOCKYARD,
20th April, 1854.



APPENDIX

No. 2.

Royal Dockyard, Woolwich,

7th February, 1854.

SIR,

The measurement of Ships' Tonnage being, now, a subject of legislation, I beg respectfully to bring before your notice that—admitting the proposed system of admeasurement to be well adapted for Mercantile and Fiscal purposes—it will, nevertheless, be useless as a datum for determining the relative merits of the constructive form and engine-adaptation thereto of steam-ships: for this purpose, in ADDITION to the *Commercial tonnage*, it is desirable that the ships' Displacement and corresponding draught be also known, namely:—

- | | | |
|---|-----------------------------|-------------------|
| 1st. Launching Draught..... | { Forward,—
Aft,.....— } | and Displacement. |
| 2nd. Light Draught ready
for Cargo | { Forward,—
Aft,.....— } | and Displacement. |
| 3rd. Loaded to Constructors'
Deep-draught line ... | { Forward,—
Aft,.....— } | and Displacement. |

These data would afford the means of ascertaining approximately the *dead weight* of cargo, and this approximate knowledge of the *dead weight*, when compared with the Mercantile tonnage or *bulk*, would be an useful Fiscal check in cases of doubt as to the declaration of cargo. As a question of science (in which alone I take an interest in this matter), I beg to observe that it is for want of registration of the Displacement of vessels in the 3 different conditions above set forth, namely,—when Launched, when Light ready to receive cargo, and when Loaded down to the constructor's Deep-draught line (which data builders rarely give, and which Merchants, not knowing the importance of it, seldom demand), that keeps the public totally in the dark as to the relative co-efficients of locomotive duty performed by different steam-ships; and it is for the want of such means of comparison, whereby constructive merit may be measured, that the models of form and of engine-adaptation best suited for Mercantile duty have not been recognised, whilst inferior vessels have infused pernicious maxims of construction.

In an "Essay on Steam Ship Capability," which you recently did me the honour of noticing, I have briefly referred to "the necessity of the available engine-power of all steamers being registered, together with the tonnage and the DISPLACEMENT at a given draught," (Preface to "Steam Ship Capability;") and I now beg further to express the opinion that the registration of *Displacement*, if followed up, would soon work out a reform in shipping affairs of great Mercantile importance.

I have the honour to be,

Sir,

Your most obedient Servant,
(Signed,) CHAS. ATHERTON.

To

Woolwich Dockyard,
1st May, 1854.

SIR,

On referring to the proposed Act for the Regulation of Merchant Shipping, it appears that the "Horse Power" of all steamers is to be registered; but no definition has been given of the amount or measure of power that is to constitute the unit of power (H.P.) I therefore beg respectfully to submit the following remarks for your consideration:—

No definite measure of power has ever been *legalized* as constituting the unit of power (H.P.) Watt originally defined the unit of power "Horse Power" as equivalent to a weight of 33,000lbs. raised 1 foot high per minute; which definite amount of power was originally acted upon, and is still recognised by engineers as the unit denoted by the term "INDICATED Horse Power," or *Ind. h.p.*; but, in all marine engine practice for many years past, this definite unit has been totally discarded. No other *definite* MEASURE of power whatever has been substituted in lieu thereof: the practice of engineers has been entirely arbitrary, and, consequently, under the general term "Horse Power," the denomination of an engine (say 350 Nominal Horse Power) does not afford any indication whatever of the working or Indicated Power capable of being developed.

For example:—

The Indicated h.p. of H. M. S. V. ENCOUNTER is double the Nominal H.P.

"	"	AGAMEMNON is 3 times	"
"	"	UNDINE is 4 ditto	"
"	"	BANSHEE is 5 ditto	"
"	"	ELFIN is 6 ditto	"

and the engines of the "BANSHEE" and "LLEWELLYN" of 350 H.P., as completed by the contractors, actually worked up to a greater amount of power than the 800 H.P. engines of the "TERRIBLE" and "RETRIBUTION."

Hence, it appears that the Nominal Horse Power by which the machinery of a vessel is designated constitutes no certain indication whatever of the working capability of the engines.

This almost incredible anomaly has been briefly referred to in my "Essay on Steam Ship Capability," page 7, to which I have the honour to refer; and in addition to the instances therein adduced of its baneful effect on the marine engine practice of the present day, I would also assert that it constitutes a source of disorganization of a most serious character.

I do not hesitate to affirm that a legalized definition of the unit of power to be denoted by the term "Horse Power" would at once conduce more than any other step whatever to the improved application of steam.

I am,

Sir,

Your most obedient Servant,
(Signed,) CHAS. ATHERTON.

To

APPENDIX
No. 3.

V.	V ²	V.	V ²	V.	V ²	V.	V ²	V.	V ²	V.	V ²	V.	V ²	V.	V ²	V.	V ²
5.00	125.00	5.70	185.19	6.40	262.14	7.10	337.91	7.80	474.55	8.50	614.12	9.20	778.69	9.90	970.30		
1	125.75	1	186.17	1	263.87	1	359.43	1	476.88	1	616.30	1	781.23	1	973.24		
2	126.51	2	187.15	2	264.61	2	360.94	2	478.21	2	618.47	2	783.78	2	976.19		
3	127.26	3	188.13	3	265.85	3	362.47	3	480.05	3	620.65	3	786.33	3	979.15		
4	128.02	4	189.12	4	267.09	4	363.99	4	481.89	4	622.84	4	788.89	4	982.11		
5	128.79	5	190.11	5	268.34	5	365.53	5	483.74	5	625.08	5	791.45	5	985.07		
6	129.56	6	191.10	6	269.59	6	367.06	6	485.59	6	627.22	6	794.02	6	988.05		
7	130.32	7	192.10	7	270.84	7	368.60	7	487.44	7	629.42	7	796.60	7	991.08		
8	131.10	8	193.10	8	272.10	8	370.15	8	489.30	8	631.63	8	799.18	8	994.01		
9	131.87	9	194.10	9	273.36	9	371.69	9	491.17	9	633.84	9	801.77	9	997.00		
5.10	132.65	5.80	195.11	6.50	274.62	7.20	373.25	7.90	493.04	8.60	636.06	9.30	804.36	10.00	1000.0		
1	133.43	1	196.12	1	275.89	1	374.81	1	494.91	1	638.28	1	806.95	1	1003.0		
2	134.22	2	197.14	2	277.17	2	376.37	2	496.79	2	640.50	2	809.56	2	1006.0		
3	135.01	3	198.16	3	278.45	3	377.93	3	498.68	3	642.74	3	812.17	3	1009.0		
4	135.80	4	199.18	4	279.73	4	379.50	4	500.57	4	644.97	4	814.78	4	1012.0		
5	136.59	5	200.20	5	281.01	5	381.08	5	502.46	5	647.21	5	817.40	5	1015.1		
6	137.39	6	201.23	6	282.30	6	382.66	6	504.36	6	649.46	6	820.08	6	1018.1		
7	138.19	7	202.26	7	283.59	7	384.24	7	506.26	7	651.71	7	822.66	7	1021.1		
8	138.99	8	203.30	8	284.89	8	385.83	8	508.17	8	653.97	8	825.29	8	1024.2		
9	139.80	9	204.34	9	286.19	9	387.42	9	510.08	9	656.28	9	827.94	9	1027.2		
5.20	140.61	5.90	205.38	6.60	287.50	7.30	389.02	8.00	512.00	8.70	658.50	9.40	830.58	10.10	1030.3		
1	141.42	1	206.48	1	288.80	1	390.62	1	513.92	1	660.78	1	833.24	1	1033.4		
2	142.24	2	207.47	2	290.12	2	392.22	2	515.85	2	663.06	2	835.90	2	1036.4		
3	143.06	3	208.53	3	291.43	3	393.83	3	517.78	3	665.34	3	838.56	3	1039.5		
4	143.88	4	209.58	4	292.75	4	395.45	4	519.72	4	667.63	4	841.23	4	1042.6		
5	144.70	5	210.64	5	294.08	5	397.07	5	521.66	5	669.92	5	843.91	5	1045.7		
6	145.53	6	211.71	6	295.41	6	398.69	6	523.61	6	672.22	6	846.59	6	1048.8		
7	146.36	7	212.78	7	296.74	7	400.32	7	525.56	7	674.53	7	849.28	7	1051.9		
8	147.20	8	213.85	8	298.08	8	401.95	8	527.51	8	676.84	8	851.97	8	1055.0		
9	148.04	9	214.92	9	299.42	9	403.58	9	529.48	9	679.15	9	854.67	9	1058.1		
5.30	148.88	6.00	216.00	6.70	300.76	7.40	405.22	8.10	531.44	8.80	681.47	9.50	857.37	10.20	1061.2		
1	149.72	1	217.08	1	302.11	1	406.87	1	533.41	1	683.80	1	860.09	1	1064.3		
2	150.57	2	218.17	2	303.46	2	408.52	2	535.39	2	686.13	2	862.80	2	1067.5		
3	151.42	3	219.26	3	304.82	3	410.17	3	537.37	3	688.47	3	865.52	3	1070.6		
4	152.27	4	220.35	4	306.18	4	411.83	4	539.35	4	690.81	4	868.25	4	1073.7		
5	153.13	5	221.45	5	307.55	5	413.49	5	541.34	5	693.15	5	870.93	5	1076.9		
6	153.99	6	222.55	6	308.92	6	415.16	6	543.34	6	695.51	6	873.72	6	1080.0		
7	154.85	7	223.65	7	310.29	7	416.83	7	545.34	7	697.86	7	876.47	7	1083.2		
8	155.72	8	224.76	8	311.67	8	418.51	8	547.34	8	700.23	8	879.22	8	1086.4		
9	156.59	9	225.87	9	313.05	9	420.19	9	549.35	9	702.60	9	881.97	9	1089.5		
5.40	157.46	6.10	226.98	6.80	314.43	7.50	421.87	8.20	551.87	8.90	704.97	9.60	884.74	10.30	1092.7		
1	158.34	1	228.10	1	315.82	1	423.56	1	553.89	1	707.85	1	887.50	1	1095.9		
2	159.22	2	229.22	2	317.21	2	425.26	2	555.41	2	709.78	2	890.28	2	1099.1		
3	160.10	3	230.35	3	318.61	3	426.96	3	557.44	3	712.12	3	893.06	3	1102.3		
4	160.99	4	231.48	4	320.01	4	428.66	4	559.48	4	714.52	4	895.84	4	1105.5		
5	161.88	5	232.61	5	321.42	5	430.37	5	561.52	5	716.92	5	898.63	5	1108.7		
6	162.77	6	233.74	6	322.83	6	432.08	6	563.56	6	719.32	6	901.43	6	1111.9		
7	163.67	7	234.89	7	324.24	7	433.80	7	565.61	7	721.78	7	904.28	7	1115.2		
8	164.57	8	236.08	8	325.66	8	435.52	8	567.66	8	724.15	8	907.04	8	1118.4		
9	165.47	9	237.18	9	327.08	9	437.25	9	569.72	9	726.57	9	909.85	9	1121.6		
5.50	166.37	6.20	238.23	6.90	328.51	7.60	438.98	8.30	571.79	9.00	729.00	9.70	912.67	10.40	1124.9		
1	167.28	1	239.48	1	329.94	1	440.71	1	573.86	1	731.43	1	915.50	1	1128.1		
2	168.20	2	240.64	2	331.37	2	442.45	2	575.93	2	733.87	2	918.33	2	1131.4		
3	169.11	3	241.80	3	332.81	3	444.19	3	578.01	3	736.81	3	921.17	3	1134.6		
4	170.03	4	242.97	4	334.26	4	445.94	4	580.09	4	738.76	4	924.01	4	1137.9		
5	170.95	5	244.14	5	335.70	5	447.70	5	582.18	5	741.22	5	926.86	5	1141.2		
6	171.88	6	245.31	6	337.15	6	449.46	6	584.28	6	743.68	6	929.71	6	1144.4		
7	172.81	7	246.49	7	338.61	7	451.22	7	586.38	7	746.14	7	932.57	7	1147.7		
8	173.74	8	247.67	8	340.07	8	452.98	8	588.48	8	748.61	8	935.44	8	1151.0		
9	174.68	9	248.86	9	341.53	9	454.76	9	590.59	9	751.09	9	938.31	9	1154.3		
5.60	175.62	6.30	250.05	7.00	343.00	7.70	456.53	8.40	592.70	9.10	753.57	9.80	941.19	10.50	1157.6		
1	176.56	1	251.24	1	344.47	1	458.31	1	594.82	1	756.06	1	944.08	1	1160.9		
2	177.50	2	252.44	2	345.95	2	460.10	2	596.95	2	758.55	2	946.97	2	1164.3		
3	178.45	3	253.64	3	347.43	3	461.89	3	599.08	3	761.05	3	949.86	3	1167.6		
4	179.41	4	254.84	4	348.91	4	463.68	4	601.21	4	763.55	4	952.76	4	1170.9		
5	180.36	5	256.05	5	350.40	5	465.48	5	603.35	5	766.06	5	955.67	5	1174.2		
6	181.32	6	257.26	6	351.90	6	467.29	6	605.50	6	768.58	6	958.59	6	1177.6		
7	182.28	7	258.47	7	353.39	7	469.10	7	607.65	7	771.10	7	961.50	7	1180.9		
8	183.25	8	259.69	8	354.89	8	470.91	8	609.80	8	773.62	8	964.43	8	1184.3		
9	184.22	9	260.92	9	356.40	9	472.73	9	611.96	9	776.15	9	967.36	9	1187.6		

v.	v ²	v.	v ²	v.	v ²	v.	v ²	v.	v ²	v.	v ²	v.	v ²
10.60	1191.0	11.30	1442.9	12.00	1728.0	12.70	2048.4	13.40	2406.1	14.10	2808.2	14.80	3241.8
1	1194.4	1	1446.7	1	1732.3	1	2053.2	1	2411.5	1	2809.2	1	3248.4
2	1197.8	2	1450.6	2	1736.7	2	2058.1	2	2416.9	2	2815.2	2	3255.0
3	1201.2	3	1454.4	3	1741.0	3	2062.9	3	2422.3	3	2821.2	3	3261.5
4	1204.6	4	1458.3	4	1745.3	4	2067.8	4	2427.7	4	2827.1	4	3268.1
5	1207.9	5	1462.1	5	1749.7	5	2072.7	5	2433.1	5	2833.1	5	3274.8
6	1211.4	6	1466.0	6	1754.0	6	2077.6	6	2438.6	6	2839.2	6	3281.4
7	1214.8	7	1469.9	7	1758.4	7	2082.4	7	2444.0	7	2845.2	7	3288.0
8	1218.2	8	1473.8	8	1762.8	8	2087.3	8	2449.5	8	2851.2	8	3294.6
9	1221.6	9	1477.6	9	1767.2	9	2092.2	9	2454.9	9	2857.2	9	3301.3
10.70	1225.0	11.40	1481.5	12.10	1771.6	12.80	2097.2	13.50	2460.4	14.20	2863.3	14.90	3307.9
1	1228.5	1	1485.4	1	1776.0	1	2102.1	1	2465.8	1	2869.3	1	3314.6
2	1231.9	2	1489.4	2	1780.4	2	2107.0	2	2471.3	2	2875.4	2	3321.3
3	1235.4	3	1493.3	3	1784.8	3	2111.9	3	2476.8	3	2881.5	3	3328.0
4	1238.8	4	1497.2	4	1789.2	4	2116.9	4	2482.3	4	2887.6	4	3334.7
5	1242.3	5	1501.1	5	1793.6	5	2121.8	5	2487.8	5	2893.6	5	3341.4
6	1245.8	6	1505.1	6	1798.0	6	2126.8	6	2493.3	6	2899.7	6	3348.1
7	1249.2	7	1509.0	7	1802.6	7	2131.7	7	2498.8	7	2905.8	7	3354.8
8	1252.7	8	1513.0	8	1806.9	8	2136.7	8	2504.4	8	2912.0	8	3361.5
9	1256.2	9	1516.9	9	1811.4	9	2141.7	9	2509.9	9	2918.1	9	3368.3
10.80	1259.7	11.50	1520.9	12.20	1815.8	12.90	2146.7	13.60	2515.5	14.30	2924.2	15.00	3375.0
1	1263.2	1	1524.8	1	1820.3	1	2151.7	1	2521.0	1	2930.3	1	3381.8
2	1266.7	2	1528.8	2	1824.8	2	2156.7	2	2526.6	2	2936.5	2	3388.5
3	1270.2	3	1532.8	3	1829.3	3	2161.7	3	2532.1	3	2942.6	3	3395.3
4	1273.8	4	1536.8	4	1833.8	4	2166.7	4	2537.7	4	2948.8	4	3402.1
5	1277.3	5	1540.8	5	1838.3	5	2171.7	5	2543.3	5	2955.0	5	3408.9
6	1280.8	6	1544.8	6	1842.8	6	2176.8	6	2548.9	6	2961.2	6	3415.7
7	1284.4	7	1548.8	7	1847.3	7	2181.8	7	2554.5	7	2967.4	7	3422.5
8	1287.9	8	1552.8	8	1851.8	8	2186.9	8	2560.1	8	2973.6	8	3429.3
9	1291.5	9	1556.9	9	1856.3	9	2191.9	9	2565.7	9	2979.8	9	3436.1
10.90	1295.0	11.60	1560.9	12.30	1860.9	13.00	2197.0	13.70	2571.4	14.40	2986.0	15.10	3443.0
1	1298.6	1	1564.9	1	1865.4	1	2202.1	1	2577.0	1	2992.2	1	3449.8
2	1302.2	2	1569.0	2	1870.0	2	2207.2	2	2582.6	2	2998.4	2	3456.6
3	1305.8	3	1573.0	3	1874.6	3	2212.2	3	2588.3	3	3004.7	3	3463.5
4	1309.3	4	1577.1	4	1879.1	4	2217.3	4	2593.9	4	3010.9	4	3470.4
5	1312.9	5	1581.2	5	1883.7	5	2222.4	5	2599.6	5	3017.2	5	3477.8
6	1316.5	6	1585.2	6	1888.2	6	2227.6	6	2605.3	6	3023.5	6	3484.2
7	1320.2	7	1589.3	7	1892.8	7	2232.7	7	2611.0	7	3029.7	7	3491.1
8	1323.8	8	1593.4	8	1897.4	8	2237.8	8	2616.7	8	3036.0	8	3498.0
9	1327.4	9	1597.5	9	1902.0	9	2242.9	9	2622.4	9	3042.3	9	3504.9
11.00	1331.0	11.70	1601.6	12.40	1906.6	13.10	2248.1	13.80	2628.1	14.50	3048.6	15.20	3511.8
1	1334.6	1	1605.7	1	1911.2	1	2253.2	1	2633.8	1	3054.9	1	3518.7
2	1338.3	2	1609.8	2	1915.9	2	2258.4	2	2639.5	2	3061.3	2	3525.7
3	1341.9	3	1614.0	3	1920.5	3	2263.6	3	2645.2	3	3067.6	3	3532.6
4	1345.6	4	1618.1	4	1925.1	4	2268.7	4	2651.0	4	3073.9	4	3539.6
5	1349.2	5	1622.2	5	1929.8	5	2273.9	5	2656.7	5	3080.3	5	3546.6
6	1352.9	6	1626.4	6	1934.4	6	2279.1	6	2662.5	6	3086.6	6	3553.6
7	1356.6	7	1630.5	7	1939.1	7	2284.8	7	2668.3	7	3093.0	7	3560.6
8	1360.3	8	1634.7	8	1943.8	8	2289.5	8	2674.0	8	3099.4	8	3567.5
9	1363.9	9	1638.9	9	1948.4	9	2294.7	9	2679.8	9	3105.7	9	3574.6
11.10	1367.6	11.80	1643.0	12.50	1953.1	13.20	2300.0	13.90	2685.6	14.60	3112.1	15.30	3581.6
1	1371.3	1	1647.2	1	1957.8	1	2305.2	1	2691.4	1	3118.5	1	3588.6
2	1375.0	2	1651.4	2	1962.5	2	2310.4	2	2697.2	2	3124.9	2	3595.6
3	1378.7	3	1655.6	3	1967.2	3	2315.7	3	2703.0	3	3131.4	3	3602.7
4	1382.5	4	1659.8	4	1971.9	4	2320.9	4	2708.9	4	3137.8	4	3609.7
5	1386.2	5	1664.0	5	1976.7	5	2326.2	5	2714.7	5	3144.2	5	3616.8
6	1389.9	6	1668.2	6	1981.4	6	2331.5	6	2720.5	6	3150.7	6	3623.9
7	1393.7	7	1672.4	7	1986.1	7	2336.8	7	2726.4	7	3157.1	7	3631.0
8	1397.4	8	1676.7	8	1990.9	8	2342.0	8	2732.3	8	3163.6	8	3638.1
9	1401.2	9	1680.9	9	1995.6	9	2347.3	9	2738.1	9	3170.0	9	3645.2
11.20	1404.9	11.90	1685.2	12.60	2000.4	13.30	2352.6	14.00	2744.0	14.70	3176.5	15.40	3652.8
1	1408.7	1	1689.4	1	2005.1	1	2357.9	1	2749.9	1	3183.0	1	3659.4
2	1412.5	2	1693.7	2	2009.9	2	2363.3	2	2755.8	2	3189.5	2	3666.5
3	1416.3	3	1697.9	3	2014.7	3	2368.6	3	2761.7	3	3196.0	3	3673.7
4	1420.0	4	1702.2	4	2019.5	4	2373.9	4	2767.6	4	3202.5	4	3680.8
5	1423.8	5	1706.5	5	2024.3	5	2379.8	5	2773.5	5	3209.0	5	3688.0
6	1427.6	6	1710.8	6	2029.1	6	2384.6	6	2779.4	6	3215.6	6	3695.1
7	1431.4	7	1715.1	7	2033.9	7	2389.0	7	2785.4	7	3222.1	7	3702.8
8	1435.2	8	1719.4	8	2038.7	8	2395.3	8	2791.3	8	3228.7	8	3709.5
9	1439.1	9	1723.7	9	2043.5	9	2400.7	9	2797.3	9	3235.2	9	3716.7

v.	v ²	v.	v ²	v.	v ²	v.	v ²	v.	v ²	v.	v ²	v.	v ²
15.50	3723.9	16.20	4251.5	16.90	4862.8	17.60	5451.8	18.30	6128.5	19.00	6859.0	19.70	7645.4
1	3731.1	1	4259.4	1	4835.4	1	5461.1	1	6138.5	1	6869.8	1	7657.0
2	3738.3	2	4267.3	2	4844.0	2	5470.4	2	6148.6	2	6880.7	2	7668.7
3	3745.5	3	4275.2	3	4852.6	3	5479.7	3	6158.7	3	6891.5	3	7680.4
4	3752.8	4	4283.1	4	4861.2	4	5489.0	4	6168.8	4	6902.4	4	7692.0
5	3760.0	5	4291.0	5	4869.8	5	5498.4	5	6178.9	5	6913.3	5	7703.7
6	3767.3	6	4298.9	6	4878.4	6	5507.7	6	6189.0	6	6924.2	6	7715.4
7	3774.6	7	4306.9	7	4887.0	7	5517.1	7	6199.1	7	6935.1	7	7727.2
8	3781.8	8	4314.8	8	4895.7	8	5526.5	8	6209.2	8	6946.0	8	7738.9
9	3789.1	9	4322.5	9	4904.3	9	5535.8	9	6219.4	9	6956.9	9	7750.6
15.60	3796.4	16.30	4330.7	17.00	4913.0	17.70	5545.2	18.40	6229.5	19.10	6967.9	19.80	7762.4
1	3803.7	1	4338.7	1	4921.7	1	5554.6	1	6239.7	1	6978.8	1	7774.2
2	3811.0	2	4346.7	2	4930.4	2	5564.1	2	6249.8	2	6989.8	2	7785.9
3	3818.4	3	4354.7	3	4939.1	3	5573.5	3	6260.0	3	7000.8	3	7797.7
4	3825.7	4	4362.7	4	4947.8	4	5582.9	4	6270.2	4	7011.7	4	7809.5
5	3833.0	5	4370.7	5	4956.5	5	5592.4	5	6280.4	5	7022.7	5	7821.3
6	3840.4	6	4378.7	6	4965.2	6	5601.8	6	6290.6	6	7033.7	6	7833.2
7	3847.8	7	4386.8	7	4973.9	7	5611.3	7	6300.9	7	7044.8	7	7845.0
8	3855.1	8	4394.8	8	4982.7	8	5620.8	8	6311.1	8	7055.8	8	7856.9
9	3862.5	9	4402.9	9	4991.4	9	5630.3	9	6321.4	9	7066.8	9	7868.7
15.70	3869.9	16.40	4410.9	17.10	5000.2	17.80	5639.8	18.50	6331.6	19.20	7077.9	19.90	7880.6
1	3877.3	1	4419.0	1	5009.0	1	5649.3	1	6341.9	1	7089.0	1	7892.5
2	3884.7	2	4427.1	2	5017.8	2	5658.8	2	6352.2	2	7100.0	2	7904.4
3	3892.1	3	4435.2	3	5026.6	3	5668.3	3	6362.5	3	7111.1	3	7916.3
4	3899.5	4	4443.3	4	5035.4	4	5677.9	4	6372.8	4	7122.2	4	7928.2
5	3907.0	5	4451.4	5	5044.2	5	5687.4	5	6383.1	5	7133.3	5	7940.2
6	3914.4	6	4459.5	6	5053.0	6	5697.0	6	6393.4	6	7144.5	6	7952.1
7	3921.9	7	4467.7	7	5061.9	7	5706.6	7	6403.8	7	7155.6	7	7964.1
8	3929.4	8	4475.8	8	5070.7	8	5716.1	8	6414.1	8	7166.7	8	7976.0
9	3936.8	9	4484.0	9	5079.6	9	5725.7	9	6424.5	9	7177.9	9	7988.0
15.80	3944.3	16.50	4492.1	17.20	5088.4	17.90	5735.3	18.60	6434.9	19.30	7189.1	20.00	8000.0
1	3951.8	1	4500.3	1	5097.3	1	5745.0	1	6445.2	1	7200.2	1	8012.0
2	3959.3	2	4508.5	2	5106.2	2	5754.6	2	6455.6	2	7211.4	2	8024.0
3	3966.8	3	4516.7	3	5115.1	3	5764.2	3	6466.0	3	7222.6	3	8036.1
4	3974.3	4	4524.9	4	5124.0	4	5773.9	4	6476.5	4	7233.8	4	8048.1
5	3981.9	5	4533.1	5	5133.0	5	5783.5	5	6486.9	5	7245.1	5	8060.2
6	3989.4	6	4541.3	6	5141.9	6	5793.2	6	6497.3	6	7256.3	6	8072.2
7	3997.0	7	4549.5	7	5150.8	7	5802.9	7	6507.8	7	7267.6	7	8084.3
8	4004.5	8	4557.8	8	5159.8	8	5812.6	8	6518.2	8	7278.8	8	8096.4
9	4012.1	9	4566.0	9	5168.7	9	5822.3	9	6528.7	9	7290.1	9	8108.5
15.90	4019.7	16.60	4574.3	17.30	5177.7	18.00	5832.0	18.70	6539.2	19.40	7301.4	20.10	8120.6
1	4027.3	1	4582.6	1	5186.7	1	5841.7	1	6549.7	1	7312.7	1	8132.7
2	4034.9	2	4590.8	2	5195.7	2	5851.5	2	6560.2	2	7324.0	2	8144.9
3	4042.5	3	4599.1	3	5204.7	3	5861.2	3	6570.7	3	7335.3	3	8157.0
4	4050.1	4	4607.4	4	5213.7	4	5871.0	4	6581.3	4	7346.6	4	8169.2
5	4057.7	5	4615.8	5	5222.7	5	5880.7	5	6591.8	5	7358.0	5	8181.4
6	4065.4	6	4624.1	6	5231.8	6	5890.5	6	6602.3	6	7369.3	6	8193.6
7	4073.0	7	4632.4	7	5240.8	7	5900.3	7	6612.9	7	7380.7	7	8205.7
8	4080.7	8	4640.7	8	5249.9	8	5910.1	8	6623.5	8	7392.1	8	8217.9
9	4088.3	9	4649.1	9	5258.9	9	5919.9	9	6634.1	9	7403.5	9	8230.2
16.00	4096.0	16.70	4657.5	17.40	5268.0	18.10	5929.7	18.80	6644.7	19.50	7414.9	20.20	8242.4
1	4103.7	1	4665.8	1	5277.1	1	5939.6	1	6655.3	1	7426.3	1	8254.7
2	4111.4	2	4674.2	2	5286.2	2	5949.4	2	6665.9	2	7437.7	2	8266.9
3	4119.1	3	4682.6	3	5295.3	3	5959.3	3	6676.5	3	7449.2	3	8279.2
4	4126.8	4	4691.0	4	5304.4	4	5969.1	4	6687.2	4	7460.6	4	8291.5
5	4134.5	5	4699.4	5	5313.6	5	5979.0	5	6697.8	5	7472.1	5	8303.8
6	4142.3	6	4707.8	6	5322.7	6	5988.9	6	6708.5	6	7483.5	6	8316.1
7	4150.0	7	4716.3	7	5331.9	7	5998.8	7	6719.2	7	7495.0	7	8328.4
8	4157.7	8	4724.7	8	5341.0	8	6008.7	8	6729.9	8	7506.5	8	8340.7
9	4165.5	9	4733.2	9	5350.2	9	6018.6	9	6740.6	9	7518.0	9	8353.1
16.10	4173.3	16.80	4741.6	17.50	5359.4	18.20	6028.6	18.90	6751.3	19.60	7529.5	20.30	8365.4
1	4181.1	1	4750.1	1	5368.6	1	6038.5	1	6762.0	1	7541.1	1	8377.7
2	4188.9	2	4758.6	2	5377.8	2	6048.5	2	6772.7	2	7552.6	2	8390.2
3	4196.7	3	4767.1	3	5387.0	3	6058.4	3	6783.5	3	7564.2	3	8402.6
4	4204.5	4	4775.6	4	5396.2	4	6068.4	4	6794.2	4	7575.7	4	8415.0
5	4212.3	5	4784.1	5	5405.4	5	6078.4	5	6805.0	5	7587.3	5	8427.4
6	4220.1	6	4792.6	6	5414.7	6	6088.4	6	6815.8	6	7598.9	6	8439.8
7	4228.0	7	4801.1	7	5423.9	7	6098.4	7	6826.6	7	7610.5	7	8452.3
8	4235.8	8	4809.7	8	5433.2	8	6108.4	8	6837.4	8	7622.1	8	8464.7
9	4243.7	9	4818.2	9	5442.5	9	6118.4	9	6848.2	9	7633.7	9	8477.2

v.	v ²	v	v ²	v.	v ²	v.	v ²	v.	v ²	v.	v ²	v.	v ²
20.40	8489.7	21.10	9889.9	21.80	10880	22.50	11891	23.20	12487	23.90	13652	24.60	14887
1	8502.2	1	9407.3	1	10874	1	11406	1	12508	1	13669	1	14905
2	8514.7	2	9420.7	2	10889	2	11421	2	12519	2	13686	2	14923
3	8527.3	3	9434.1	3	10408	3	11436	3	12536	3	13703	3	14941
4	8539.7	4	9447.5	4	10417	4	11451	4	12552	4	13721	4	14960
5	8552.2	5	9460.9	5	10432	5	11467	5	12568	5	13738	5	14978
6	8564.8	6	9474.3	6	10446	6	11482	6	12584	6	13755	6	14996
7	8577.4	7	9487.7	7	10460	7	11497	7	12601	7	13772	7	15014
8	8589.9	8	9501.2	8	10475	8	11513	8	12617	8	13789	8	15033
9	8602.5	9	9514.7	9	10489	9	11528	9	12633	9	13807	9	15051
20.50	8615.1	21.20	9528.1	21.90	10503	22.60	11543	23.30	12649	24.00	13824	24.70	15069
1	8627.7	1	9541.6	1	10518	1	11559	1	12666	1	13841	1	15088
2	8640.4	2	9555.1	2	10532	2	11574	2	12682	2	13859	2	15106
3	8653.0	3	9568.6	3	10547	3	11589	3	12698	3	13876	3	15124
4	8665.7	4	9582.2	4	10561	4	11605	4	12715	4	13893	4	15143
5	8678.3	5	9595.7	5	10576	5	11620	5	12731	5	13911	5	15161
6	8691.0	6	9609.3	6	10590	6	11635	6	12747	6	13928	6	15179
7	8703.7	7	9622.8	7	10604	7	11651	7	12764	7	13945	7	15198
8	8716.4	8	9636.4	8	10619	8	11666	8	12780	8	13963	8	15216
9	8729.1	9	9650.0	9	10633	9	11682	9	12796	9	13980	9	15235
20.60	8741.8	21.30	9663.6	22.00	10648	22.70	11697	23.40	12813	24.10	13998	24.80	15253
1	8754.6	1	9677.2	1	10663	1	11713	1	12829	1	14015	1	15271
2	8767.3	2	9690.8	2	10677	2	11728	2	12846	2	14032	2	15290
3	8780.1	3	9704.5	3	10692	3	11744	3	12862	3	14050	3	15308
4	8792.8	4	9718.1	4	10706	4	11759	4	12879	4	14067	4	15327
5	8805.6	5	9731.8	5	10721	5	11775	5	12895	5	14085	5	15345
6	8818.4	6	9745.5	6	10735	6	11790	6	12912	6	14102	6	15364
7	8831.2	7	9759.2	7	10750	7	11806	7	12928	7	14120	7	15383
8	8844.1	8	9772.9	8	10765	8	11821	8	12945	8	14137	8	15401
9	8856.9	9	9786.6	9	10779	9	11837	9	12961	9	14155	9	15420
20.70	8869.7	21.40	9800.3	22.10	10794	22.80	11852	23.50	12978	24.20	14172	24.90	15438
1	8882.6	1	9814.1	1	10809	1	11868	1	12994	1	14190	1	15457
2	8895.5	2	9827.8	2	10823	2	11884	2	13011	2	14208	2	15475
3	8908.4	3	9841.6	3	10838	3	11899	3	13028	3	14225	3	15494
4	8921.3	4	9855.4	4	10853	4	11915	4	13044	4	14243	4	15513
5	8934.2	5	9869.2	5	10867	5	11930	5	13061	5	14261	5	15531
6	8947.1	6	9883.0	6	10882	6	11946	6	13078	6	14278	6	15550
7	8960.0	7	9896.8	7	10897	7	11962	7	13094	7	14296	7	15569
8	8973.0	8	9910.7	8	10912	8	11978	8	13111	8	14314	8	15588
9	8985.9	9	9924.5	9	10926	9	11993	9	13128	9	14331	9	15606
20.80	8998.9	21.50	9938.4	22.20	10941	22.90	12009	23.60	13144	24.30	14349	25.00	15625
1	9011.9	1	9952.2	1	10956	1	12025	1	13161	1	14367	..	..
2	9024.9	2	9966.1	2	10971	2	12040	2	13178	2	14384	..	..
3	9037.9	3	9980.0	3	10985	3	12056	3	13194	3	14402	..	..
4	9050.9	4	9993.9	4	11000	4	12072	4	13211	4	14420	..	..
5	9064.0	5	10008	5	11015	5	12088	5	13228	5	14438	..	..
6	9077.0	6	10022	6	11030	6	12104	6	13245	6	14455	..	..
7	9090.1	7	10036	7	11045	7	12119	7	13262	7	14473	..	..
8	9103.1	8	10050	8	11060	8	12135	8	13278	8	14491	..	..
9	9116.2	9	10064	9	11075	9	12151	9	13295	9	14509	..	..
20.90	9129.3	21.60	10078	22.30	11090	23.00	12167	23.70	13312	24.40	14527	..	..
1	9142.4	1	10092	1	11104	1	12183	1	13329	1	14545	..	..
2	9155.6	2	10106	2	11119	2	12199	2	13346	2	14563	..	..
3	9168.7	3	10120	3	11134	3	12215	3	13363	3	14580	..	..
4	9181.8	4	10134	4	11149	4	12231	4	13380	4	14598	..	..
5	9195.0	5	10148	5	11164	5	12247	5	13396	5	14616	..	..
6	9208.2	6	10162	6	11179	6	12262	6	13413	6	14634	..	..
7	9221.4	7	10176	7	11194	7	12278	7	13430	7	14652	..	..
8	9234.6	8	10190	8	11209	8	12294	8	13447	8	14670	..	..
9	9247.8	9	10204	9	11224	9	12310	9	13464	9	14688	..	..
21.00	9261.0	21.70	10218	22.40	11239	23.10	12326	23.80	13481	24.50	14706	..	..
1	9274.2	1	10232	1	11254	1	12342	1	13498	1	14724	..	..
2	9287.5	2	10247	2	11270	2	12358	2	13515	2	14742	..	..
3	9300.7	3	10261	3	11285	3	12374	3	13532	3	14760	..	..
4	9314.0	4	10275	4	11300	4	12391	4	13549	4	14778	..	..
5	9327.3	5	10289	5	11315	5	12407	5	13566	5	14796	..	..
6	9340.6	6	10303	6	11330	6	12423	6	13583	6	14814	..	..
7	9353.9	7	10318	7	11345	7	12439	7	13601	7	14833	..	..
8	9367.2	8	10332	8	11360	8	12455	8	13618	8	14851	..	..
9	9380.6	9	10346	9	11375	9	12471	9	13635	9	14869	..	..

D.	D ₁	D.	D ₁	D.	D ₁	D.	D ₁	D.	D ₁	D.	D ₁	D.	D ₁
		500	62.996	1200	112.92	1900	153.41	2600	189.08	3300	221.66	4000	251.98
		10	63.833	10	113.55	10	153.94	10	189.57	10	222.10	10	252.40
10	4.6416	20	64.665	20	114.18	20	154.43	20	190.05	20	222.55	20	252.82
15	6.0822	30	65.491	30	114.80	30	155.01	30	190.58	30	223.00	30	253.24
20	7.3681	40	66.313	40	115.42	40	155.55	40	191.02	40	223.45	40	253.66
25	8.5499	50	67.129	50	116.04	50	156.08	50	191.50	50	223.89	50	254.08
30	9.6549	60	67.940	60	116.66	60	156.62	60	191.98	60	224.33	60	254.50
35	10.700	70	68.746	70	117.27	70	157.15	70	192.46	70	224.78	70	254.91
40	11.696	80	69.548	80	117.89	80	157.68	80	192.94	80	225.22	80	255.33
45	12.651	90	70.345	90	118.50	90	158.21	90	193.42	90	225.67	90	255.75
50	13.572	600	71.188	1300	119.11	2000	158.74	2700	193.90	3400	226.11	4100	256.16
55	14.462	10	71.926	10	119.72	10	159.27	10	194.38	10	226.55	10	256.58
60	15.326	20	72.710	20	120.33	20	159.79	20	194.86	20	227.00	20	257.00
65	16.166	30	73.490	30	120.94	30	160.32	30	195.33	30	227.44	30	257.41
70	16.985	40	74.266	40	121.54	40	160.85	40	195.82	40	227.88	40	257.83
75	17.784	50	75.036	50	122.15	50	161.37	50	196.29	50	228.32	50	258.24
80	18.566	60	75.805	60	122.75	60	161.90	60	196.76	60	228.76	60	258.66
85	19.332	70	76.568	70	123.35	70	162.42	70	197.24	70	229.20	70	259.07
90	20.083	80	77.328	80	123.95	80	162.95	80	197.71	80	229.64	80	259.49
95	20.820	90	78.085	90	124.55	90	163.47	90	198.18	90	230.08	90	259.90
100	21.544	700	78.887	1400	125.15	2100	163.99	2800	198.66	3500	230.52	4200	260.32
05	22.256	10	79.586	10	125.74	10	164.51	10	199.13	10	230.96	10	260.73
10	22.958	20	80.382	20	126.33	20	165.03	20	199.60	20	231.40	20	261.14
15	23.649	30	81.074	30	126.93	30	165.55	30	200.07	30	231.84	30	261.55
20	24.329	40	81.815	40	127.52	40	166.06	40	200.54	40	232.27	40	261.96
25	25.000	50	82.549	50	128.11	50	166.58	50	201.01	50	232.71	50	262.38
30	25.662	60	83.283	60	128.69	60	167.10	60	201.49	60	233.15	60	262.79
35	26.316	70	84.009	70	129.28	70	167.61	70	201.96	70	233.58	70	263.20
40	26.962	80	84.735	80	129.87	80	168.12	80	202.42	80	234.02	80	263.61
45	27.600	90	85.458	90	130.45	90	168.64	90	202.89	90	234.46	90	264.03
150	28.231	800	86.176	1500	131.04	2200	169.15	2900	203.36	3600	234.89	4300	264.46
55	28.855	10	86.894	10	131.62	10	169.66	10	203.83	10	235.33	10	264.88
60	29.472	20	87.608	20	132.20	20	170.18	20	204.29	20	235.76	20	265.25
65	30.083	30	88.319	30	132.78	30	170.69	30	204.76	30	236.19	30	265.66
70	30.688	40	89.026	40	133.36	40	171.20	40	205.22	40	236.63	40	266.07
75	31.286	50	89.732	50	133.93	50	171.71	50	205.69	50	237.06	50	266.48
80	31.880	60	90.434	60	134.51	60	172.21	60	206.16	60	237.49	60	266.88
85	32.467	70	91.133	70	135.08	70	172.72	70	206.62	70	237.93	70	267.29
90	33.049	80	91.831	80	135.66	80	173.23	80	207.08	80	238.36	80	267.70
95	33.627	90	92.525	90	136.23	90	173.74	90	207.55	90	238.79	90	268.11
200	34.200	900	93.217	1600	136.80	2300	174.24	3000	208.01	3700	239.22	4400	268.52
10	35.380	10	93.906	10	137.36	10	174.75	10	208.47	10	239.65	10	268.92
20	36.443	20	94.593	20	137.93	20	175.25	20	208.93	20	240.08	20	269.33
30	37.589	30	95.277	30	138.50	30	175.75	30	209.39	30	240.51	30	269.73
40	38.620	40	95.959	40	139.07	40	176.26	40	209.86	40	240.94	40	270.14
50	39.685	50	96.638	50	139.63	50	176.76	50	210.31	50	241.37	50	270.55
60	40.787	60	97.316	60	140.19	60	177.26	60	210.77	60	241.80	60	270.96
70	41.774	70	97.990	70	140.76	70	177.76	70	211.23	70	242.23	70	271.36
80	42.799	80	98.662	80	141.32	80	178.26	80	211.69	80	242.66	80	271.76
90	43.812	90	99.332	90	141.88	90	178.76	90	212.15	90	243.08	90	272.16
300	44.814	1000	100.00	1700	142.44	2400	179.26	3100	212.60	3800	243.51	4500	272.57
10	45.804	10	100.67	10	143.00	10	179.76	10	213.06	10	243.94	10	272.97
20	46.784	20	101.33	20	143.56	20	180.25	20	213.52	20	244.37	20	273.37
30	47.754	30	101.99	30	144.11	30	180.76	30	213.98	30	244.79	30	273.78
40	48.714	40	102.65	40	144.66	40	181.24	40	214.43	40	245.22	40	274.18
50	49.664	50	103.31	50	145.22	50	181.74	50	214.89	50	245.64	50	274.58
60	50.606	60	103.96	60	145.77	60	182.23	60	215.34	60	246.07	60	274.99
70	51.539	70	104.61	70	146.32	70	182.73	70	215.80	70	246.49	70	275.39
80	52.464	80	105.27	80	146.87	80	183.22	80	216.25	80	246.92	80	275.79
90	53.380	90	105.91	90	147.42	90	183.71	90	216.70	90	247.34	90	276.19
400	54.288	1100	106.56	1800	147.97	2500	184.20	3200	217.15	3900	247.76	4600	276.59
10	55.189	10	107.21	10	148.52	10	184.70	10	217.61	10	248.19	10	276.99
20	56.083	20	107.85	20	149.07	20	185.19	20	218.06	20	248.61	20	277.39
30	56.970	30	108.49	30	149.61	30	185.67	30	218.51	30	249.04	30	277.79
40	57.848	40	109.12	40	150.16	40	186.16	40	218.95	40	249.46	40	278.19
50	58.723	50	109.76	50	150.70	50	186.65	50	219.40	50	249.88	50	278.59
60	59.590	60	110.40	60	151.24	60	187.14	60	219.85	60	250.30	60	278.99
70	60.451	70	111.03	70	151.78	70	187.62	70	220.31	70	250.72	70	279.39
80	61.304	80	111.67	80	152.33	80	188.11	80	220.76	80	251.14	80	279.79
90	62.153	90	112.30	90	152.87	90	188.60	90	221.21	90	251.56	90	280.19

D.	D $\frac{1}{2}$	D.	D $\frac{1}{2}$	D.	D $\frac{1}{2}$	D.	D $\frac{1}{2}$	D.	D $\frac{1}{2}$	D.	D $\frac{1}{2}$	D.	D $\frac{1}{2}$	D.	D $\frac{1}{2}$
4700	280.59	5400	307.80	6100	333.86	6800	358.96	7500	383.17	8200	408.64	8900	429.46		
10	280.98	10	308.18	10	334.22	10	359.28	10	383.50	10	409.97	10	429.79		
20	281.88	20	308.56	20	334.58	20	359.63	20	383.84	20	407.30	20	429.11		
30	281.78	30	308.96	30	334.96	30	359.98	30	384.18	30	407.63	30	430.43		
40	282.17	40	309.31	40	335.31	40	360.33	40	384.52	40	407.96	40	430.75		
50	282.57	50	309.69	50	335.67	50	360.68	50	384.86	50	408.29	50	431.07		
60	282.97	60	310.07	60	336.04	60	361.04	60	385.20	60	408.62	60	431.39		
70	283.36	70	310.45	70	336.40	70	361.39	70	385.54	70	408.96	70	431.71		
80	283.76	80	310.83	80	336.76	80	361.74	80	385.87	80	409.28	80	432.03		
90	284.16	90	311.21	90	337.12	90	362.09	90	386.21	90	409.61	90	432.35		
4800	284.55	5500	311.59	6200	337.49	6900	362.45	7600	386.55	8300	409.94	9000	432.67		
10	284.95	10	311.96	10	337.85	10	362.79	10	386.89	10	410.27	10	433.00		
20	285.34	20	312.34	20	338.21	20	363.14	20	387.23	20	410.59	20	433.32		
30	285.74	30	312.72	30	338.56	30	363.49	30	387.57	30	410.92	30	433.64		
40	286.13	40	313.09	40	338.94	40	363.84	40	387.91	40	411.25	40	433.96		
50	286.52	50	313.47	50	339.30	50	364.19	50	388.25	50	411.58	50	434.28		
60	286.92	60	313.84	60	339.66	60	364.53	60	388.58	60	411.91	60	434.60		
70	287.31	70	314.22	70	340.02	70	364.88	70	388.92	70	412.24	70	434.92		
80	287.70	80	314.60	80	340.39	80	365.23	80	389.26	80	412.57	80	435.23		
90	288.10	90	314.97	90	340.75	90	365.59	90	389.60	90	412.90	90	435.55		
4900	288.49	5600	315.35	6300	341.11	7000	365.95	7700	389.94	8400	413.23	9100	435.87		
10	288.88	10	315.72	10	341.47	10	366.29	10	390.28	10	413.56	10	436.19		
20	289.28	20	316.10	20	341.83	20	366.63	20	390.61	20	413.88	20	436.51		
30	289.67	30	316.47	30	342.19	30	366.98	30	390.95	30	414.21	30	436.83		
40	290.06	40	316.85	40	342.55	40	367.32	40	391.29	40	414.54	40	437.15		
50	290.45	50	317.22	50	342.91	50	367.67	50	391.62	50	414.86	50	437.47		
60	290.84	60	317.60	60	343.27	60	368.02	60	391.96	60	415.19	60	437.79		
70	291.23	70	317.97	70	343.63	70	368.37	70	392.30	70	415.52	70	438.11		
80	291.62	80	318.34	80	343.99	80	368.71	80	392.63	80	415.84	80	438.42		
90	292.01	90	318.72	90	344.34	90	369.06	90	392.97	90	416.17	90	438.74		
5000	292.40	5700	319.09	6400	344.70	7100	369.41	7800	393.31	8500	416.50	9200	439.06		
10	292.79	10	319.46	10	345.07	10	369.75	10	393.64	10	416.83	10	439.38		
20	293.18	20	319.84	20	345.43	20	370.10	20	393.98	20	417.15	20	439.70		
30	293.57	30	320.21	30	345.78	30	370.44	30	394.31	30	417.48	30	440.01		
40	293.96	40	320.58	40	346.14	40	370.79	40	394.65	40	417.80	40	440.33		
50	294.35	50	320.96	50	346.50	50	371.14	50	394.98	50	418.13	50	440.65		
60	294.74	60	321.33	60	346.86	60	371.49	60	395.32	60	418.45	60	440.97		
70	295.13	70	321.70	70	347.21	70	371.83	70	395.65	70	418.78	70	441.29		
80	295.51	80	322.07	80	347.57	80	372.18	80	395.99	80	419.11	80	441.61		
90	295.90	90	322.44	90	347.93	90	372.52	90	396.31	90	419.44	90	441.92		
5100	296.29	5800	322.82	6500	348.29	7200	372.87	7900	396.64	8600	419.76	9300	442.24		
10	296.67	10	323.19	10	348.64	10	373.21	10	396.98	10	420.08	10	442.56		
20	297.06	20	323.56	20	349.00	20	373.56	20	397.33	20	420.41	20	442.88		
30	297.45	30	323.93	30	349.36	30	373.90	30	397.66	30	420.74	30	443.19		
40	297.83	40	324.30	40	349.72	40	374.25	40	398.00	40	421.06	40	443.51		
50	298.22	50	324.67	50	350.07	50	374.59	50	398.33	50	421.39	50	443.82		
60	298.61	60	325.04	60	350.43	60	374.94	60	398.67	60	421.71	60	444.14		
70	298.99	70	325.40	70	350.79	70	375.28	70	399.00	70	422.04	70	444.46		
80	299.38	80	325.77	80	351.14	80	375.62	80	399.33	80	422.36	80	444.78		
90	299.76	90	326.14	90	351.50	90	375.96	90	399.67	90	422.68	90	445.09		
5200	300.15	5900	326.51	6600	351.85	7300	376.30	8000	400.00	8700	423.01	9400	445.41		
10	300.53	10	326.88	10	352.20	10	376.65	10	400.33	10	423.33	10	445.73		
20	300.92	20	327.25	20	352.56	20	377.00	20	400.67	20	423.65	20	446.05		
30	301.30	30	327.62	30	352.92	30	377.34	30	401.00	30	423.98	30	446.36		
40	301.68	40	327.99	40	353.28	40	377.69	40	401.33	40	424.30	40	446.68		
50	302.07	50	328.36	50	353.62	50	378.03	50	401.66	50	424.63	50	446.99		
60	302.45	60	328.72	60	353.98	60	378.37	60	402.00	60	424.95	60	447.31		
70	302.84	70	329.09	70	354.33	70	378.71	70	402.33	70	425.28	70	447.62		
80	303.22	80	329.46	80	354.69	80	379.06	80	402.67	80	425.60	80	447.93		
90	303.60	90	329.83	90	355.04	90	379.40	90	403.00	90	425.92	90	448.25		
5300	303.98	6000	330.20	6700	355.40	7400	379.74	8100	403.33	8800	426.25	9500	448.56		
10	304.36	10	330.56	10	355.75	10	380.08	10	403.66	10	426.57	10	448.87		
20	304.75	20	330.93	20	356.10	20	380.42	20	403.99	20	426.89	20	449.18		
30	305.13	30	331.29	30	356.45	30	380.76	30	404.32	30	427.21	30	449.50		
40	305.51	40	331.66	40	356.81	40	381.11	40	404.65	40	427.53	40	449.81		
50	305.89	50	332.03	50	357.16	50	381.45	50	404.98	50	427.86	50	450.13		
60	306.27	60	332.40	60	357.52	60	381.79	60	405.32	60	428.18	60	450.44		
70	306.65	70	332.77	70	357.87	70	382.13	70	405.65	70	428.50	70	450.76		
80	307.03	80	333.13	80	358.22	80	382.47	80	405.98	80	428.82	80	451.07		
90	307.41	90	333.49	90	358.57	90	382.82	90	406.31	90	429.14	90	451.38		

D.	D ₂	D.	D ₂	D.	D ₂	D.	D ₂	D.	D ₂	D.	D ₂
9600	451.70	10000	464.16	14000	580.88	18000	686.83	22000	785.14	30000	965.49
10	452.01	100	467.25	100	583.64	100	689.37	100	787.52	30500	976.19
20	452.32	200	470.33	200	586.40	200	691.91	200	789.90	31000	986.83
30	452.64	300	473.39	300	589.15	300	694.44	300	792.27	31500	997.41
40	452.95	400	476.46	400	591.89	400	696.96	400	794.63	32000	1007.9
50	453.26	500	479.50	500	594.82	500	699.49	500	797.00	32500	1018.4
60	453.58	600	482.54	600	597.84	600	702.01	600	799.36	33000	1028.8
70	453.89	700	485.57	700	600.06	700	704.52	700	801.71	33500	1039.2
80	454.20	800	488.59	800	602.78	800	707.03	800	804.06	34000	1049.5
90	454.52	900	491.60	900	605.52	900	709.53	900	806.41	34500	1059.8
9700	454.83	11000	494.61	15000	608.22	19000	712.04	23000	808.76	35000	1070.0
10	455.14	100	497.60	100	615.93	100	714.53	100	811.10	35500	1080.2
20	455.45	200	500.59	200	613.62	200	717.02	200	813.44	36000	1090.3
30	455.77	300	503.56	300	616.31	300	719.51	300	815.78	36500	1100.3
40	456.08	400	506.53	400	618.99	400	722.00	400	818.11	37000	1110.4
50	456.39	500	509.48	500	621.66	500	724.48	500	820.44	37500	1120.3
60	456.70	600	512.48	600	624.33	600	726.95	600	822.76	38000	1130.3
70	457.02	700	515.37	700	627.00	700	729.42	700	825.08	38500	1140.2
80	457.33	800	518.31	800	629.66	800	731.89	800	827.40	39000	1150.0
90	457.64	900	521.23	900	632.31	900	734.85	900	829.72	39500	1159.8
9800	457.95	12000	524.15	16000	634.96	20000	736.81	24000	832.03	40000	1169.6
10	458.26	100	527.06	100	637.60	100	739.26	100	834.34	40500	1179.3
20	458.58	200	529.96	200	640.24	200	741.71	200	836.65	41000	1189.0
30	458.89	300	532.85	300	642.87	300	744.16	300	838.95	41500	1198.7
40	459.20	400	535.73	400	645.50	400	746.60	400	841.24	42000	1208.3
50	459.51	500	538.60	500	648.12	500	749.07	500	843.54	42500	1217.8
60	459.82	600	541.48	600	650.74	600	751.44	600	845.84	43000	1227.4
70	460.13	700	544.34	700	653.35	700	753.89	700	848.13	43500	1236.9
80	460.44	800	547.19	800	655.95	800	756.33	800	850.42	44000	1246.3
90	460.75	900	550.04	900	658.55	900	758.75	900	852.71	44500	1255.7
9900	461.06	13000	552.88	17000	661.15	21000	761.17	25000	854.99	45000	1265.1
10	461.37	100	555.71	100	663.74	100	763.59	25500	856.35	45500	1274.5
20	461.68	200	558.53	200	666.33	200	766.00	26000	877.64	46000	1283.8
30	461.99	300	561.35	300	668.91	300	768.40	26500	888.85	46500	1293.1
40	462.30	400	564.16	400	671.49	400	770.80	27000	900.00	47000	1302.4
50	462.61	500	566.96	500	674.06	500	773.20	27500	911.08	47500	1311.6
60	462.92	600	569.75	600	676.62	600	775.60	28000	922.09	48000	1320.8
70	463.23	700	572.55	700	679.18	700	777.99	28500	933.03	48500	1329.9
80	463.54	800	575.33	800	681.74	800	780.38	29000	943.91	49000	1339.1
90	463.85	900	578.11	900	684.29	900	782.76	29500	954.73	50000	1357.2

APPENDIX
No. 4.

*Dimensions, Trial Data, and Deduced Index Number or
Co-efficient of Dynamic Quality of H.M. Steam-vessels*

	RATTLE.	REYNARD.	FAIRY.
Date of trial at the Measured Knot in the Thames	28rd Jan., '45	14th July, '48	5th April, '45
Length between the Perpendiculars	176ft. 6 in.	147ft. 8 in.	144ft. 8 in.
Breadth, extreme.....	32 8½	27 10	21 1½
Mean Draught of Water at time of trial.....	13 6	9 6	4 10
Ratio of { Length to Breadth	5.39	5.30	6.84
{ Draught to Breadth	.41	.34	.28
Area of immersed Midship Section	330ft.	184ft.	71.5ft.
DISPLACEMENT at time of trial—tons weight	1078	478	168
Diameter of Cylinders	4 of 40½	2 of 28	2 of 42
Length of Stroke.....	4ft.	2ft.	3ft.
Revolutions per minute during trial	26.98	54.43	51.6
Mean pressure on Piston per square in. by Ind.	13.2lbs.	20.27lbs.	14.00lbs.
Working Power in lbs. raised 1 foot per minute...	14,411,100	5,435,100	12,005,400
HORSE POWER { Assuming 33,000lbs. 1ft. $\frac{1}{2}$ min. $\frac{1}{2}$ h.p.	436.70	164.70	363.80
{ " 100,000lbs " H.P.	144.11	54.35	120.05
{ " 132,000lbs " " "	109.17	41.17	90.95
SPEED of Vessels per hour in knots	9.64	8.24	13.32
Diameter of Screw-Propeller	10ft. 0in.	8ft. 9in.	5ft. 4in.
Pitch of ditto	11 0	8 0	8 0
Length of ditto	1 3	1 4	1 0
Multiple of Gearing	4 to 1	2 to 1	5 to 1
Revolutions of Screw per minute	107.92	108.86	258
Slip per cent.....	17.67	4.09	34.55
INDEX NUMBERS by formula $\frac{V^3 D^4}{H.P.} = C$,			
Assuming the unit of Power at 33,000lbs 1 ft. $\frac{1}{2}$ m.	215.60	207.50	197.90
" " " 100,000lbs " "	653.33	628.80	599.70
" " " 132,000lbs " "	862.40	830	791.60
Ratio of { Displacement in feet to L × B × D	.50	.44	.41
{ Midship Section to B × D	.75	.70	.70
{ Length of Forebody to Afterbody } measuring to the Screw aperture)	46 to 54		
Cubic ft. of Displacement $\frac{1}{2}$ Ind. h.p.....	89	105	17
Square ft. of immersed Mid. Sec. $\frac{1}{2}$ Ind. h.p.....	.76	1.12	.20
* { Nominal Horse-power.....	200	60	128
{ " Tonnage (Builder's Measurement)...	888	516	312

* The Nominal Horse-power having no definite ratio to the working-power of the Engines and the Tonnage having no definite ratio to the Ships' Displacement, these quantities do not constitute data whereby the Dynamic Qualities of Ships of different Type can be compared.

The Index Number or Co-efficient deduced from the formula $\frac{V^3 D^3}{H.P.} = C$ constitutes a comparative test of the Dynamic or Locomotive Quality of Vessels merely as dependant on the respective types of form, combined with their Engine efficiency; this co-efficient does not embrace the *economic* efficiency of the Engine Department as dependant on the consumption of fuel in proportion to the effective Power of the Engines. If however in the above formula we substitute the total consumption of Coals per hour, expressed in cwts. (W), (presuming the Coals to be of constant quality) instead of the Horse-Power (H.P.) the result of the formula $\frac{V^3 D^3}{W}$ will give a number expressive of the comparative Dynamic duty performed by the respective ships, and this comparative test will be more generally available inasmuch as the average consumption of Coals (W), is a Mercantile expenditure more generally and more correctly known than the average working-power of the Engines (H.P.)

For example:—Suppose the required average speed on a passage of 3,600 nautical miles to be 13 knots per hour, and that a Ship (A), of which the Deep-draught Displacement is 3,600 tons, perform the required service with a consumption of 1,200 tons of Coals. In this case the speed (V) being 13 knots per hour, the time of passage will be 277 hours; the average consumption of Coals (W) will be 86.64 cwts. per hour, and the Mid-passage Displacement will be 3,000 tons, consequently the Co-efficient of Dynamic Duty of this ship ($\frac{V^3 D^3}{W}$) will be represented by the number $\frac{2197 \times 208.01}{86.64} = 5273$.

Again, suppose another ship (B) of which the Deep-draught Displacement is 1,500 tons to make the same passage in the same time (277 hours) with a consumption of 600 tons of Coal, in this case the consumption of Coal (W) will be at the rate of 43.32 cwts. per hour, and the Mid-passage Displacement will be 1,200 tons, consequently the Dynamic Duty of this ship will be represented by the number $\frac{2197 \times 112.92}{43.32} = 5727$. Hence, it appears that as regards the performance of Dynamic or Locomotive Duty, the type of form combined with machinery adaptation thereto of the ship B is superior to that of ship A; nevertheless, it may be less profitably adapted to the Service referred to, in consequence of the constructive weight of the Hull and Machinery, together with the Coal required for this 3,600 mile passage being performed at 13 knots per hour by a ship of such reduced size, leaving too small a proportion of the Displacement available for paying Cargo, whereby this ship, though of surpassing Dynamic Quality, may be comparatively unfit for the service;—it is only by detecting the cause of failure that error can be corrected. Commercial rivalry will undoubtedly render a correct appreciation of the Dynamic QUALITIES of ships, and the judicious *adaptation* of ships to the Service required of them, essential elements of DIRECTORIAL administration, without which no Steam enterprise can be successfully prosecuted, unless specially circumstanced to the exclusion of equal COMPETITION.







